IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

CAMERON INTERNATIONAL CORPORATION,	)	
Plaintiff,	)	C.A. No. 06-728-JJF
v.	)	
	)	**JURY DEMANDED**
DRIL-QUIP, INC.	)	
Defendant.	)	

DEFENDANT DRIL-QUIP, INC.'S ANSWER, DEFENSES, AND COUNTERCLAIMS IN RESPONSE TO PLAINTIFF'S AMENDED COMPLAINT FOR PATENT INFRINGEMENT

Defendant Dril-Quip, Inc. ("Dril-Quip") files the following amended answer, defenses, and counterclaims in response to Plaintiff Cameron International Corporation's Amended Complaint for Patent Infringement.

Answers to Plaintiff's Allegations of Patent Infringement

Dril-Quip answers the allegations in the separately numbered paragraphs of Plaintiff's Amended Complaint for Patent Infringement as follows:

1. Dril-Quip admits that this Court has subject matter jurisdiction under 28 U.S.C. §§ 1331 and 1338(a) over actions arising under the patent laws of the United States.

2. Dril-Quip admits that it is a Delaware corporation and is subject to personal jurisdiction in this District. Dril-Quip further admits that 28 U.S.C. §§ 1391(b) and (c) and 28 U.S.C. § 1400(b) confer venue in this District. Dril-Quip contends, however, that for the convenience of the parties and witnesses, and in the interest of

justice, venue is more appropriate in the Southern District of Texas. Accordingly, Dril-Quip has filed a motion to transfer venue pursuant to 28 U.S.C. § 1404(a).

3. Dril-Quip is without sufficient information to form a belief as to the truth or falsity of the allegations in Paragraph 3 and therefore denies same.

4. Dril-Quip admits that Cameron is in the business of providing products for use in subsea oil extraction and production. Dril-Quip denies the remaining allegations of Paragraph 4.

5. Dril-Quip admits that it is a Delaware corporation and that it has a principal place of business at 13550 Hempstead Highway, Houston, Texas 77040.

6. Dril-Quip admits that it conducts business in various countries around the world, including Scotland and Singapore.

7. Dril-Quip admits that United States Patent No. 7,117,945 ("the '945 patent") is entitled "Well Operations System," that it issued on October 10, 2006, and that a copy of the '945 patent was attached to Plaintiff's Amended Complaint as Exhibit A. Dril-Quip denies that the '945 patent was "duly and legally issued by the United States Patent Office." Dril-Quip is without sufficient information to form a belief as to the truth or falsity of the remaining allegations in Paragraph 7 and therefore denies same.

8. Dril-Quip denies the allegations of Paragraph 8.

9. Dril-Quip denies the allegations of Paragraph 9.

10. Dril-Quip denies the allegations of Paragraph 10.

11. Dril-Quip admits that United States Patent No. 7,093,660 ("the '660 patent") is entitled "Well Operations Assembly," that it issued on August 22, 2006, and that a copy of the '660 patent was attached to Plaintiff's Amended Complaint as Exhibit

B. Dril-Quip denies that the '660 patent was "duly and legally issued by the United States Patent Office." Dril-Quip is without sufficient information to form a belief as to the truth or falsity of the remaining allegations in Paragraph 11 and therefore denies same.

12. Dril-Quip denies the allegations of Paragraph 12.

13. Dril-Quip denies the allegations of Paragraph 13.

14. Dril-Quip denies the allegations of Paragraph 14.

15. Dril-Quip admits that United States Patent No. 6,991,039 ("the '039 patent") is entitled "Well Operations System," that it issued on January 31, 2006, and that a copy of the '039 patent was attached to Plaintiff's Amended Complaint as Exhibit C. Dril-Quip denies that the '039 patent was "duly and legally issued by the United States Patent Office." Dril-Quip is without sufficient information to form a belief as to the truth or falsity of the remaining allegations in Paragraph 15 and therefore denies same.

16. Dril-Quip denies the allegations of Paragraph 16.

17. Dril-Quip denies the allegations of Paragraph 17.

18. Dril-Quip denies the allegations of Paragraph 18.

Response to Plaintiff's Requested Relief

The allegations in the paragraph requesting relief are in the nature of prayer. Although no answer is required, Dril-Quip responds to the individual requests for relief as follows:

A. Dril-Quip denies Plaintiff is entitled to the requested injunctive relief and denies any and all liability for Plaintiff's claims.

B. Dril-Quip denies Plaintiff is entitled to any damages award (including any prejudgment and post-judgment interest) and denies any and all liability for Plaintiff's claims. C. Dril-Quip denies Plaintiff is entitled to the requested finding of willful infringement and/or to an award of enhanced damages and denies any and all liability for Plaintiff's claims.

D. Dril-Quip denies Plaintiff is entitled to a finding that this is an exceptional case and denies any and all liability for Plaintiff's claims.

E. Dril-Quip denies Plaintiff is entitled to recover its reasonable expenses, including attorneys' fees and costs incurred in prosecuting this action, and denies any and all liability for Plaintiff's claims.

F. Dril-Quip denies any and all liability for the alleged conduct, denies that any relief sought by Plaintiff is warranted, and requests that Plaintiff's requested relief be denied.

DEFENSES

Failure To State A Claim Upon Which Relief Can Be Granted

1. With respect to the allegations against Dril-Quip, Plaintiff's Complaint fails to state a claim upon which relief may be granted.

Non-Infringement

2. Dril-Quip has not infringed and does not infringe any of the claims of the '945 patent, the '660 patent, or the '039 patent (collectively referred to as "the patents-in-suit") literally, under the doctrine of equivalents, directly, contributorily, by inducement, or in any other manner.

Patent Invalidity

3. The claims of the patents-in-suit are invalid for failing to comply with the conditions and requirements for patentability as set forth in the United States Patent Laws, Title 35 U.S.C., including specifically §§ 102, 103, and/or 112 and the rules, regulations, and laws pertaining thereto.

Prosecution History Estoppel

4. Because of proceedings in the United States Patent and Trademark Office during the prosecution of the applications that resulted in the patents-in-suit, as shown by the prosecution histories thereof, Plaintiff is estopped to claim a construction of the patents-in-suit that would cause any valid claim thereof to cover or include any products that are or have been manufactured, used, sold or offered for sale by Dril-Quip, either literally or under the doctrine of equivalents.

5. Plaintiff is estopped by reason of prosecution history estoppel from asserting infringement of the patents-in-suit under the doctrine of equivalents.

Inequitable Conduct

6. Plaintiff's allegations of infringement of the patents-in-suit are barred because the patents-in-suit are unenforceable pursuant to 37 C.F.R. § 1.56 and the doctrine of inequitable conduct. The bases for and specifics of Dril-Quip's inequitable conduct defense are set forth in detail in Dril-Quip's declaratory judgment count seeking a declaration that the patents-in-suit, as well as additional related patents, are unenforceable based on Plaintiff's inequitable conduct in the procurement of those patents.

Patent Misuse

7. Plaintiff has attempted in bad faith and with an improper purpose to impermissibly broaden the physical or temporal scope of the rights granted under the patents-in-suit resulting in anticompetitive effect and, thus, the patents-in-suit are unenforceable.

Bad Faith

8. Plaintiff has brought this suit in bad faith making it an exceptional case, thereby entitling Dril-Quip to its costs and attorneys fees pursuant to 35 U.S.C. § 285.

No Irreparable Harm

9. Plaintiff is not entitled to injunctive relief because any injury to Plaintiff is not immediate or irreparable, and Plaintiff has an adequate remedy at law.

WHEREFORE Dril-Quip prays that this Court dismiss Plaintiff's action and enter judgment that Plaintiff take nothing on its claims against Dril-Quip and award Dril-Quip its attorneys' fees and costs of defending this action and such other and further relief as it may be entitled.

COUNTERCLAIMS

Facts Common To All Counts In Dril-Quip's Counterclaims

The Hopper Patents Family Tree

1. Each of the patents that are the subject of Dril-Quip's counterclaims for declaratory judgment relief identifies Hans Paul Hopper and Thomas G. Cassity as named inventors. Each of these patents is related and ultimately claims priority to a "parent" European Patent Application.

2. Specifically, European Patent Application Serial No. 92305014 was filed on June 1, 1992 ("the European Application") by Cameron's London-based patent attorney Peter Jackson based on the authorization of Cameron's United States patent agent Joe Parris.

3. On May 28, 1993, Cameron filed a PCT application that was assigned Application Number PCT/US93/05246 ("the PCT Application"). The PCT Application claims priority to the European Application.

4. On March 16, 1994, Cameron filed U.S. Patent Application No. 08/204,397 ("the '397 application") in the United States Patent and Trademark Office ("USPTO"), which is the U.S. national-phase application that is a continuation of the PCT Application. The '397 application ultimately issued on August 13, 1996, as U.S. Patent No. 5,544,707 ("the '707 patent"). A copy of the '707 patent is attached hereto as Exhibit A.

5. On July 12, 1996, Cameron filed U.S. Patent Application No. 08/679,560 ("the '560 application") in the USPTO, which is a continuation application of the '397 application. The '560 application ultimately issued on March 21, 2000, as U.S. Patent No. 6,039,119 ("the '119 patent"). A copy of the '119 patent is attached hereto as Exhibit B.

6. On June 5, 1998, Cameron filed U.S. Patent Application No. 09/092,549 ("the '549 application") in the USPTO, which is a divisional application of the '560 application. Cameron ultimately abandoned the '549 application. Before abandoning the '549 application, on September 7, 2000, Cameron filed U.S. Patent Application No. 09/657,018 ("the '018 application") in the USPTO, which is a continuation application of

the '549 application. The '018 application ultimately issued on April 15, 2003, as U.S. Patent No. 6,547,008 ("the '008 patent"). A copy of the '008 patent is attached hereto as Exhibit C.

7. On February 13, 2003, Cameron filed U.S. Patent Application No. 10/366,173 ("the '173 application") in the USPTO, which is a divisional application of the '018 application. The '173 application ultimately issued on August 22, 2006, as the '660 patent.

8. On May 13, 2004, Cameron filed U.S. Patent Application No. 10/844,871 ("the '871 application") in the USPTO, which is a divisional application of the '173 application. The '871 application ultimately issued on January 31, 2006, as the '039 patent.

9. On March 10, 2005, Cameron filed U.S. Patent Application No. 11/078,121 ("the '121 application") in the USPTO, which is a divisional application of the '173 application. The '121 application ultimately issued on October 10, 2006, as the '945 patent.[1]

10. Consistent with USPTO procedures, and in light of the relationship of each of the patents identified above (the '707 patent, the '119 patent, the '008 patent, the '660 patent, the '039 patent, and the '945 patent – collectively referred to herein as "the Hopper patents"), the Hopper patents all have a common specification and figures. That

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[1] Although not currently involved in this dispute, Cameron has filed additional patent applications that are divisional applications of the '121 and '173 applications. These divisional applications remain pending in the USPTO. For the same reasons as set forth herein, any patents that ultimately issue from these divisional applications will be equally unenforceable.

is, with respect to describing the purported invention claimed in the patents, the specification of each of the Hopper patents is identical.[2]

Parties

11. Dril-Quip is a corporation organized and existing under the laws of the State of Delaware with a principal place of business in Houston, Texas.

12. Upon information and belief, Plaintiff Cameron International Corporation ("Cameron") is a corporation organized and existing under the laws of the State of Delaware and maintains its corporate offices in Houston, Texas. As Cameron is the plaintiff in the above-captioned action, Cameron may be served with a copy of this Counterclaim by serving this document in accordance with Rule 5 of the Federal Rules of Civil Procedure.

Jurisdiction And Venue

13. This Court has subject matter jurisdiction over Dril-Quip's counterclaims pursuant to 28 U.S.C. §§ 2201-2202, 1338 and 1331.

14. A real, immediate, and justiciable controversy exists between Dril-Quip and Cameron. The controversy relates to the invalidity, non-infringement, and unenforceability of the collective Hopper patents – the patents-in-suit (the '660 patent, the '039 patent, and the '945 patent) and the additional Hopper patents identified herein (the '707 patent, the '119 patent, and the '008 patent).

15. Specifically, Cameron has accused Dril-Quip of infringing the patents-in-suit. As noted herein, the patents-in-suit and the additional Hopper patents all claim

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[2] The specification of each of the Hopper patents subsequent to the '707 patent does, however, contain an additional paragraph regarding the relationship of the patents.

priority to the European Application. Given the relationship between the Hopper patents, all of the patents in this family of patents have a common specification and figures, and all of the patents claim a subsea wellhead apparatus and/or method of using such apparatus. As such, the claims of each of the patents in this family of patents cover the same general subject matter and may be asserted against Dril-Quip in this or a subsequent action.

16. Indeed, Cameron has previously asserted one or more of the Hopper patents (not the patents-in-suit) against Dril-Quip. As early as August 1996, Cameron's in-house intellectual property counsel, Mr. Peter Bielinski, sent correspondence to Dril-Quip asserting that Dril-Quip may be infringing the '707 patent and offering to license the '707 patent. Subsequently, the parties discussed potential license terms for a license to – *inter alia* – the '707 patent. These discussions continued up through at least August 2006.

17. Similarly, in November 2000, Cameron's outside litigation counsel, Mr. Lester Hewitt, sent correspondence to Dril-Quip asserting that Dril-Quip was infringing the '119 patent and indicating Cameron's willingness to license the '119 patent. Subsequently, the parties discussed potential license terms for a license to – *inter alia* – the '119 patent. These discussions continued up through at least August 2006.

18. Similarly, in October 2004, Cameron's in-house intellectual property counsel, Mr. Bielinski, sent additional correspondence to Dril-Quip asserting that Dril-Quip had infringed the '008 patent. Subsequently, the parties discussed potential license terms for a license to – *inter alia* – the '008 patent. These discussions continued up through at least August 2006.

19. In light of Cameron's previous allegations that Dril-Quip was infringing the '707, '119, and '008 patents, and in light of the parties' negotiations concerning a potential license to these patents – negotiations that continued through at least August 2006, there is a definite and concrete dispute between Dril-Quip and Cameron as to the alleged infringement of the Hopper family patents and the invalidity and unenforceability of those patents. A declaratory judgment as to those issues will conclusively resolve the dispute. Furthermore, Dril-Quip has a reasonable and immediate apprehension that Cameron may assert any or all of these patents in this or a subsequent action and, therefore, seeks to resolve any disputes with Cameron concerning the alleged infringement of the entire family of Hopper patents in this action.

20. Cameron is subject to personal jurisdiction and venue in the District of Delaware by virtue of its incorporation under the laws of the State of Delaware. As the plaintiff in the above-captioned lawsuit, Cameron has consented to jurisdiction and venue in this Court. Dril-Quip contends, however, that for the convenience of the parties and witnesses, and in the interest of justice, venue is more appropriate in the Southern District of Texas. Accordingly, Dril-Quip has filed a motion to transfer venue pursuant to 28 U.S.C. § 1404(a).

Count 1: Declaratory Judgment of Patent Invalidity

21. Dril-Quip incorporates by reference each preceding allegation as though expressly stated herein.

22. The claims in the '945 patent are invalid for failing to comply with the conditions and requirements for patentability as set forth in the United States Patent

Laws, Title 35 U.S.C., including specifically §§ 102, 103, and/or 112 and the rules, regulations, and laws pertaining thereto.

23. The claims in the '039 patent are invalid for failing to comply with the conditions and requirements for patentability as set forth in the United States Patent Laws, Title 35 U.S.C., including specifically §§ 102, 103, and/or 112 and the rules, regulations, and laws pertaining thereto.

24. The claims in the '660 patent are invalid for failing to comply with the conditions and requirements for patentability as set forth in the United States Patent Laws, Title 35 U.S.C., including specifically §§ 102, 103, and/or 112 and the rules, regulations, and laws pertaining thereto.

25. The claims in the '008 patent are invalid for failing to comply with the conditions and requirements for patentability as set forth in the United States Patent Laws, Title 35 U.S.C., including specifically §§ 102, 103, and/or 112 and the rules, regulations, and laws pertaining thereto.

26. The claims in the '119 patent are invalid for failing to comply with the conditions and requirements for patentability as set forth in the United States Patent Laws, Title 35 U.S.C., including specifically §§ 102, 103, and/or 112 and the rules, regulations, and laws pertaining thereto.

27. The claims in the '707 patent are invalid for failing to comply with the conditions and requirements for patentability as set forth in the United States Patent Laws, Title 35 U.S.C., including specifically §§ 102, 103, and/or 112 and the rules, regulations, and laws pertaining thereto.

28. Accordingly, Dril-Quip seeks a declaratory judgment pursuant to 28 U.S.C. §§ 2201-2202 that the '945 patent, the '039 patent, the '660 patent, the '008 patent, the '119 patent, and the '707 patent are invalid.

Count 2: Declaratory Judgment of Non-Infringement

29. Dril-Quip incorporates by reference each preceding allegation as though expressly stated herein.

30. Dril-Quip has not infringed and does not infringe any of the claims of the '945 patent literally, under the doctrine of equivalents, directly, contributorily, by inducement, or in any other manner.

31. Dril-Quip has not infringed and does not infringe any of the claims of the '039 patent literally, under the doctrine of equivalents, directly, contributorily, by inducement, or in any other manner.

32. Dril-Quip has not infringed and does not infringe any of the claims of the '660 patent literally, under the doctrine of equivalents, directly, contributorily, by inducement, or in any other manner.

33. Dril-Quip has not infringed and does not infringe any of the claims of the '008 patent literally, under the doctrine of equivalents, directly, contributorily, by inducement, or in any other manner.

34. Dril-Quip has not infringed and does not infringe any of the claims of the '119 patent literally, under the doctrine of equivalents, directly, contributorily, by inducement, or in any other manner.

35. Dril-Quip has not infringed and does not infringe any of the claims of the '707 patent literally, under the doctrine of equivalents, directly, contributorily, by inducement, or in any other manner.

36. Accordingly, Dril-Quip seeks a declaratory judgment pursuant to 28 U.S.C. §§ 2201-2202 that it has not infringed (and does not infringe) any valid claim of the '945 patent, the '039 patent, the '660 patent, the '008 patent, the '119 patent, and/or the '707 patent.

Count 3: Declaratory Judgment of Unenforceability of Patents

37. Dril-Quip incorporates by reference each preceding allegation as though expressly stated herein.

38. As set forth below, Cameron has committed inequitable conduct during the prosecution of the Hopper patents. Pursuant to the doctrine of infectious unenforceability, Cameron's inequitable conduct pervades the prosecution of the entire family of Hopper patents.

39. Specifically, as set forth below, Cameron's inequitable conduct began during the prosecution of the '707 patent with Cameron's fraudulent revival of the abandoned national phase applications and the failure to name the true inventor of the inventions claimed in the Hopper patents.

40. Cameron's conduct renders the '707 patent unenforceable. Each of the subsequent Hopper patents is also unenforceable because those patents are related to the '707 patent and there is an immediate and necessary relation between the alleged inequitable conduct and the enforcement of those related patents.

41. In particular, had Cameron not fraudulently revived its abandoned United States national phase application, Cameron would not be entitled to claim priority to the European Application or the PCT Application. If Cameron cannot claim priority to those applications, those applications are considered prior art to the original United States application (the '397 application) and would invalidate each of the Hopper patents. As such, Cameron's fraudulent revival of the United States national phase application is connected to and of consequence to the subsequent prosecutions of – and enforcement of – all of the Hopper patents identified herein (the '707 patent, the '119 patent, the '008 patent, the '660 patent, the '039 patent, and the '945 patent).

42. Likewise, Cameron's failure to identify the true inventor of the invention(s) claimed in the Hopper patents renders each of the Hopper patents invalid. As such, Cameron's failure to name the true inventor is connected to and of consequence to the subsequent prosecutions of – and enforcement of – all of the Hopper patents identified herein (the '707 patent, the '119 patent, the '008 patent, the '660 patent, the '039 patent, and the '945 patent).

43. Cameron's inequitable conduct continued with – *inter alia* – the withholding of material prior art references from the USPTO during the prosecution of the '707 patent with the intent to deceive. This prior art is material to the patentability of claims in each of the Hopper patents. Under controlling authority, Cameron's disclosure of this initially withheld prior art during the prosecution of the subsequent Hopper patents is insufficient to cure Cameron's inequitable conduct based on the original withholding of these references. As such, Cameron's withholding of material prior art references during the prosecution of the '707 patent (and the continued withholding of additional material

information during the prosecution of the subsequent Hopper patents) is connected to and of consequence to the subsequent prosecutions of – and enforcement of – all of the Hopper patents identified herein (the '707 patent, the '119 patent, the '008 patent, the '660 patent, the '039 patent, and the '945 patent).

44. Accordingly, Cameron's assertion of the patents-in-suit and the additional Hopper patents against Dril-Quip is barred because those patents are unenforceable pursuant to 37 C.F.R. § 1.56 and the doctrine of inequitable conduct.

Cameron's Duty Of Candor To The USPTO

45. Applicants for patents are required to prosecute patent applications in the USPTO with candor, good faith, and honesty (hereinafter "the duty of candor"). The duty of candor specifically entails – *inter alia* – the disclosure of information of which the applicants are aware that is material to the examination of the application. The duty of candor also prohibits applicants from making material misrepresentations to the examiners at the USPTO.

46. The duty of candor is codified at 37 C.F.R. §1.56 and applies to "each individual associated with the filing and prosecution of a patent application," including attorneys, agents, and inventors.

47. As noted above, the United States national-phase application (the '397 application) was filed on March 16, 1994, from which time Cameron owed the duty of candor to the USPTO, including the duty to disclose material prior art to the USPTO.

48. The parties that were directly involved in the prosecution of the '397 application include: (a) the inventors, Messrs. Hopper and Cassity; (b) Cameron's English patent agent, Mr. Jackson; (c) two of Cameron's in-house patent attorneys, Bruce

Patterson and Allen Thiele; and (d) Cameron's General Manager of Patent Services, Joe Parris (a patent agent).

49. Pursuant to 37 C.F.R. § 1.56, the duty of candor to the USPTO applied to each of these individuals during the prosecution of the '397 application.

50. With respect to the prosecutions of the subsequent patent applications that are related to the '397 application, Messrs. Hopper and Cassity had continued involvement in those prosecutions. Cameron's outside patent prosecution counsel, David Rose and Shawn Hunter, were also responsible for the prosecutions of those patent applications. Likewise, Cameron's outside litigation counsel, Lester Hewitt, had a duty to provide Cameron's prosecution counsel with material information discovered during Cameron's lawsuit involving the '707 and '119 patents. As such, each of these individuals had a continuing duty of candor that existed throughout the prosecution of the Hopper patents.

<u>Cameron's Inequitable Conduct</u>

51. Cameron's repeated failures to disclose prior art and other material information to the USPTO during the prosecution of one or more of the Hopper patents were direct violations of its duty of candor.

52. Additionally, Cameron made material misrepresentations to the USPTO during the prosecutions of the Hopper patents that constitute direct violations of its duty of candor. Upon information and belief, such violations were committed with the intent to deceive the USPTO into issuing the Hopper patents.

53. As such, the Hopper patents are unenforceable as a result of Cameron's inequitable conduct, the specifics of which are set forth in the following paragraphs.

A. Cameron's Withholding Of Material Prior Art With The Intent To Deceive

1. Cameron's Failure To Disclose Material Prior Art To The USPTO During The Prosecution Of The '707 Patent

54. At least four individuals associated with the prosecution of the '397 patent application failed in their duty of disclosure to the USPTO.

55. At least six material prior art references, known to one or more of these individuals, were not disclosed because of a collective intent to mislead the examiner and the PTO.

56. Inequitable conduct as to any one of these six references would render the Hopper patents unenforceable.

a. SISL Presentation Paper SPE 23050

57. Subsea Intervention Systems Ltd. ("SISL"), a United Kingdom-based joint venture, presented Paper SPE 23050 at the Offshore Europe Conference in September 1991.

58. The subject of the paper is a horizontal Christmas tree for use with submersible pumps.

59. A model of the tree discussed in the paper was also presented at the conference.

60. The design of the SISL horizontal tree is almost identical to the claims of Cameron's '707 patent.

61. The paper is material to the '707 patent's claims as originally filed in the United States on May 28, 1993, because all of the elements of at least original claim 1, the broadest claim, are disclosed.

62. Indeed, the SISL SPE 23050 reference completely anticipates claim 1 as filed, a claim which was withdrawn March 13, 1995.

63. In addition, the horizontal tree disclosed in the SPE 23050 paper discloses several elements of claim 10 (as allowed in the '707 patent) that are missing from the few references located and reviewed by the USPTO examiner.

64. Specifically, the SPE paper discloses a workover port and a tubing annulus port that are "interconnected via an external loop line containing at least one valve."

65. None of the references before the examiner during the prosecution of the '707 patent included this element.

66. The SPE 23050 reference is not cumulative of the references located and reviewed by the USPTO examiner because of these additional elements.

67. Accordingly, the SPE 23050 paper is material to the '707 patent's claims as originally filed in the United States.

68. Hans Hopper attended the Offshore Europe Conference in September 1991.

69. Mr. Hopper knew about the SISL reference at least that early.

70. Further, Gus Cassity, Mr. Hopper's alleged co-inventor, was also aware of the SISL horizontal tree in 1992.

71. Upon information and belief, Mr. Cassity discussed the SISL horizontal tree with Mr. Hopper prior to the issuance of the '707 patent.

72. Mr. Cassity was also aware of the SISL paper prior to the issuance of the '707 patent.

73. Despite this knowledge, the SPE 23050 paper was not disclosed to the USPTO during the prosecution of the '707 patent.

b. SISL Reports

74. Numerous horizontal tree designs were developed by SISL in or about the late 1980s and the early 1990s.

75. These various designs were developed and introduced by SISL in reports that were distributed to the participating oil companies and filed in the European Economic Community ("EEC") library.

76. Specifically, the SISL Conceptual Report and the SISL 2d Interim Report contain a number of additional designs with variations that are material to the subject matter of claim 10 of the '707 patent.

77. These two reports were distributed in January 1991 and June 1991 respectively.

78. The SISL reports contain a number of variations on the drawing of SPE paper 23050. For example, drawing DR-SIS-004-003 contained in the January 1991 conceptual report shows an earlier version of the SPE 23050 design – one that contains an opening in the tree cap closed by a "wireline plug."

79. Drawing SK-SIS-004-025, also contained in the Conceptual Report, shows the bore through the tree "sealed above the tubing hanger by means of a second removable stopper plug."

80. Because both of the drawings contain elements of claim 10 of the '707 patent that are not in the references located and reviewed by the USPTO examiner, and

because both drawings completely anticipate claim 1 of the '707 patent as originally filed, these SISL reports are material to the patentability of those claims.

81. Mr. Hopper had prior knowledge of the SISL project from his time at British Petroleum ("BP").

82. Moreover, Mr. Hopper had contacts with Martin Bowring, the project manager for SISL, on numerous occasions in 1991.

83. Mr. Hopper even noted details of the SISL project in his diary as early as January 14, 1991.

84. Further, Mr. Hopper reviewed numerous SISL drawings with Steve Hatton, who worked with Mr. Hopper on the development of the purported invention claimed in the Hopper patents, on a regular basis in 1991.

85. Moreover, the SISL designs were not confidential, and the participant oil companies who received these reports were free to share the information as they saw fit.

86. Mr. Hopper knew of the EEC's involvement in the SISL project and knew representatives of all of the participants.

87. Because Mr. Hopper was at BP at the time the SISL Conceptual Report was published, and was still a BP employee at the time the SISL 2d Interim Report was published, Mr. Hopper had access to these reports.

88. Upon information and belief, Mr. Hopper was aware of and had reviewed the designs identified in the SISL Conceptual Report and the SISL 2d Interim Report as early as 1991.

89. Despite this fact, SISL the Conceptual Report and the SISL 2d Interim Report were not disclosed to the USPTO during the prosecution of the '707 patent.

c. Amoco Designs

90. In 1989, Amoco requested that Cameron submit a design study on a horizontal tree for use with submersible pumps.

91. In response to Amoco's request, Cameron submitted designs for a horizontal tree for use with submersible pumps in July 1989 ("the Amoco designs").

92. The Amoco designs include many – if not all – of the elements of the originally filed claim 1 of the '707 patent.

93. Moreover, the Amoco designs include many – if not all – of the elements recited in claim 10 of the '707 patent.

94. Thus, the existence of the Amoco designs was material evidence suggesting that the same or a similar apparatus claimed in the '707 patent was on sale in the United States more than one year prior to the filing date of the '397 application, another prior art consideration. *See* 35 U.S.C. § 102(b).

95. Mr. Cassity was the engineering manager of the department preparing the Amoco designs in 1989 and, as such, was aware of the designs at that time.

96. Mr. Hopper learned of the Amoco designs at least as early as November 1991.

97. Mr. Hopper received and reviewed at least one drawing of the Amoco designs prior to filing the '397 application.

98. Mr. Hopper knew the Amoco designs were prior art.

99. In response to concerns from Cameron employees questioning the merits of the European Application, Mr. Hopper prepared a chart in 1992 distinguishing the Amoco designs from certain of the original claims of that application.

100. Mr. Cassity recognized that the reason Mr. Hopper compared the Amoco designs to the claims as filed in the European Application was because the Amoco designs were considered prior art.

101. Further, both Mr. Parris and Mr. Jackson were aware of the Amoco designs prior to the filing of the European Application.

102. For example, on May 28, 1992, Mr. Parris sent Mr. Jackson and Mr. Hopper drawings of the Amoco designs.

103. Messrs. Parris and Jackson were also recipients of Mr. Hopper's prior art analysis that compared the claims of the European Application to the Amoco drawings.

104. Despite the fact that Messrs. Hopper, Cassity, Parris, and Jackson all knew of the prior art Amoco designs, and despite the fact that each of them knew of Mr. Hopper's comparison of the Amoco designs to the claims of the European Application, none of them ever disclosed this prior art to the USPTO during the prosecution of the '707 patent.

d. <u>Framo Designs And Patent Applications</u>

105. In January 1992, consistent with European patent laws, a patent application by Framo directed to a horizontal tree for use with a submersible pump was published internationally.

106. The Framo reference discloses a horizontal Christmas tree with a first plug above the tubing hanger and optionally a "second removable stopper plug," as claimed in claim 10 of the '707 patent.

107. In addition, it contains a workover port "interconnected via an external loop line containing at least one valve" to a tubing annulus fluid port.

108. The disclosure of a workover port and external loop is missing from the references that were located and reviewed by the USPTO examiner.

109. Thus, the Framo reference is not cumulative of those references and is material to the patentability of one or more claims of the '707 patent.

110. Cameron personnel admitted the materiality of the Framo design in a November 24, 1992 memo by characterizing the design as a "spool type tree" – just like the "SpoolTree" described in the '707 patent.

111. Mr. Hopper was aware of the Framo reference during the prosecution of the '707 patent.

112. Upon information and belief, Mr. Hopper received a copy of the Framo reference and the Cameron memo discussing it in December 1992.

113. In addition, Mr. Hopper had knowledge of the Framo design from visits with Framo to review the Framo system at least as early as 1991.

114. As such, Mr. Hopper was aware of the Framo design even before the '397 application was filed.

115. Further, upon information and belief, Mr. Parris was also aware of the Framo designs.

116. None of the applicants or agents involved in the prosecution of the '707 patent disclosed the Framo designs or reference to the USPTO.

e. The Graser Patent Application

117. The Graser patent application was filed in the United Kingdom on July 14, 1987 and was published on January 27, 1988.

118. The Graser patent application discloses a horizontal tree with an internal "stopper plug."

119. This internal plug is an important feature of the purported invention claimed in Cameron's '707 patent.

120. The Graser patent application also discloses that the internal plug "contains at least one opening closed by a wireline plug."

121. None of the references located and reviewed by the USPTO examiner disclosed this combination recited as an element of the '707 patent claims.

122. Moreover, the Graser patent application discloses all of the elements of claim 1 of the '707 patent as filed.

123. The Graser patent application is therefore material and not cumulative prior art.

124. In June 1992, after the European Application was filed, Mr. Hopper requested that Mr. Jackson perform a prior art search.

125. Mr. Jackson conducted a prior art search and provided a copy of the search report and two references to Mr. Hopper.

126. The Graser patent application was referenced in the search report provided to Mr. Hopper.

127. Mr. Hopper had the search report and obtained a copy of the Graser patent application.

128. Neither Mr. Hopper nor Mr. Jackson ever disclosed the Graser patent application to the USPTO during the prosecution of the '707 patent (or for that matter any of the other references identified in the search report).

f. Cameron's 1991 Proposal To Phillips Petroleum

129. In 1991, Cameron made a proposal to sell a tree design to Phillips Petroleum for its Ann field ("the Phillips proposal").

130. This design was not a horizontal tree; however, it included an annulus bypass – one of the limitations of the horizontal tree claimed in the '707 patent.

131. An annulus bypass is a way to access the annular area between the tubing and the casing of a well, while "bypassing" the tubing hanger.

132. The annulus bypass of claim 10 of the '707 patent consists of a workover port extending laterally through the wall of the tree, and a tubing annulus fluid port extending laterally through the wall of the tree, interconnected via an external loop line containing at least one valve.

133. All of these elements are disclosed in the Phillips proposal, but they are not in the references that were located and reviewed by the USPTO examiner during the prosecution of the '707 patent.

134. The Phillips proposal is therefore material and not cumulative.

135. Prior to the submission of the Phillips proposal in November 1991, Mr. Cassity was the engineering manager in Houston overseeing this project.

136. During his work on this project, Mr. Cassity purportedly conceived of the annulus bypass described in the Phillips proposal.

137. Mr. Cassity suggested the annulus bypass to Mr. Hopper during the development of the purported invention claimed in the '707 patent, and prior to filing the '397 application.

138. Despite the fact that Mr. Cassity was aware of the Phillips proposal, which incorporated the annulus bypass design, he never disclosed that prior art to the USPTO.

2. Cameron Withheld The Prior Art References With The Intent To Deceive The USPTO

139. Messrs. Hopper, Cassity, Parris, and Jackson were all aware of their duty of candor during the prosecution of the '707 patent.

140. Each of these individuals had prior patent prosecution experience and had knowledge of their disclosure obligations.

141. Despite this knowledge, each of these individuals withheld highly material prior art references from the USPTO during the prosecution of the '707 patent.

142. The materiality of the withheld references and the fact that not a single reference was disclosed to the USPTO examiner are evidence of intent to deceive.

143. Indeed, in view of the high degree of materiality of the withheld references, it is asserted that Cameron engaged in a well-planned deception in order to obtain the '707 patent.

144. Accordingly, upon information and belief, the prior art references discussed in the preceding paragraphs were withheld from the USPTO with the intent to deceive the examiner into allowing the '707 patent.

B. Cameron's Failure To Identify The True Inventor Of The Invention Claimed In The Hopper Patents

145. Cameron also engaged in inequitable conduct by not disclosing that the purported invention of the '707 patent was derived from others. This inequitable conduct also renders the '707 patent unenforceable.

146. Specifically, Robert Lilley developed the idea of a horizontal tree in 1984 while working for ABB Vetco Gray ("Vetco").

147. Mr. Lilley sought patent protection for the idea by submitting an invention disclosure to Vetco in 1988.

148. Vetco chose not to file for patent protection (due at least in part to the existence of the Graser patent application), but it used Mr. Lilley's design as the basis for the SISL designs of the SPE 23050 paper and the SISL reports (discussed in section A above).

149. Subsequently, due to his interest in Mr. Lilley's design (by then the SISL design), Mr. Hopper contacted Mr. Lilley in 1989 to discuss the SISL tree design, including a discussion of the annulus bypass of claim 10 of the '707 patent.

150. After their discussion, Mr. Lilley sent Mr. Hopper copies of certain annotated horizontal tree drawings.

151. The information Mr. Lilley provided to Mr. Hopper is material in a number of regards: (1) it discloses all of the elements of claim 1 of the '707 patent as originally filed; and (2) it discloses many of the elements of claim 10 of the issued '707 patent, including the annulus bypass.

152. Moreover, the information Mr. Lilley provided to Mr. Hopper shows that the invention of claims 1 and 10 of the '707 patent was not invented by Messrs. Hopper and Cassity, but rather was invented by Mr. Lilley.

153. The horizontal tree and annulus bypass information was received from Mr. Lilley prior to November 1991, Mr. Hopper's earliest date of conception.

154. As such, the information received from Mr. Lilley is at least the starting point for the purported invention claimed in the Hopper patents.

155. Upon information and belief, Cameron did not identify Mr. Lilley as a named inventor, however, because he was not a Cameron employee, and Cameron would have had to share rights to the '707 patent (and subsequent Hopper patents) with Mr. Lilley and/or Vetco.

156. This failure to name Mr. Lilley as an inventor on the '707 patent is an independent bar to patentability under 35 U.S.C. §102(f).

157. Upon information and belief, Cameron did not identify Mr. Lilley as a named inventor based on an intent to deceive the USPTO into issuing the '707 patent to someone other than the true inventor of the invention claimed in that patent.

158. The extremely high level of materiality of the information Mr. Lilley disclosed to Mr. Hopper, when coupled with Mr. Hopper's failure to disclose this information to the USPTO, is evidence of an intent to deceive the USPTO.

C. <u>Cameron's Fraudulent Revival Of The Abandoned National Phase Patent Applications</u>

159. Cameron has also committed inequitable conduct by submitting a fraudulent affidavit to the USPTO in an attempt to revive its abandoned United States national phase patent application based off of Cameron's PCT Application.

160. Specifically, in March of 1993, prior to filing the PCT Application, Mr. Parris informed Mr. Thiele that he wanted to file national applications in several countries, including the United States, Canada, and Norway, using the European Application priority date.

161. Instead of filing national applications in these countries, Cameron filed the PCT Application.

162. The filing of the PCT Application provided Cameron with additional time to determine whether or not to file national applications in the requested countries.

163. Based on the filing of the PCT Application, Cameron had until February 1, 1994 to file its PCT national phase applications, including the filing of an application in the USPTO.

164. Cameron failed to file any national applications prior to the February 1, 1994 deadline and, as such, the right to pursue patent protection in the various countries identified by Mr. Parris was rebuttably forfeited and the national phase applications became abandoned.

165. Cameron subsequently decided that it wished to nationalize the PCT Application and attempted to revive applications in the United States, Norway, Canada, Brazil, Australia, and Singapore.

166. In order to meet the standard of revival in the United States that the abandonment was unintentional, Cameron submitted a petition to the USPTO stating that its failure to file on time was "inadvertent and wholly unintentional."

167. Due to this representation, the U.S. national application was revived.

168. Cameron's petition was supported by an affidavit of Mr. Patterson in which Mr. Patterson declares that the abandonment of the United States national application was unintentional.

169. Upon information and belief, Mr. Patterson made this representation to the USPTO without making any investigation into the facts surrounding Cameron's failure to meet the February 1, 1994 filing deadline.

170. An investigation would have revealed that the filing deadline had appeared on both Mr. Thiele's and Mr. Patterson's monthly dockets for at least the two months prior to the deadline, yet neither took any action to begin preparing to file nationally until after the deadline had passed.

171. Upon information and belief, it was Cameron's practice to begin preparing national phase applications well in advance of the filing deadline for those applications.

172. An investigation by Mr. Patterson would have revealed, however, that no such preparations for filing any national phase applications based on the PCT Application were begun until after the February 1, 1994 filing deadline had passed.

173. Upon information and belief, Cameron's failure to file the United States national application prior to the February 1, 1994 filing deadline was not unintentional.

174. As such, Mr. Patterson's affidavit in support of Cameron's petition to revive that application included material misrepresentations.

175. The submission of Mr. Patterson's affidavit was material as, without it, the '707 application would have remained abandoned and never issued.

176. Upon information and belief, Cameron submitted Mr. Patterson's affidavit with the intent of deceiving the USPTO into reviving the abandoned United States national phase application.

D. **<u>Cameron's Misrepresentations Regarding The Teachings Of The Sangesland References During The Prosecution Of The '119 Patent</u>**

177. Cameron has also committed inequitable conduct by failing to disclose sworn statements and testimony of two prior art inventors that directly contradict arguments Cameron made to the USPTO to secure allowance of the '119 patent.

178. Specifically, Cameron previously asserted the '119 patent against Kvaerner Oilfield Products, Inc. in a patent infringement action styled *Cooper Cameron Corp. v. Kvaerner Oilfield Prods. Inc.*, Civ. No. H-97-0155, in the Southern District of Texas, Houston Division ("the '119 patent litigation").

179. During the '119 patent litigation, prior art documents by Professor Sigbjorn Sangesland that were material to the patentability of the claims of the Hopper patents were disclosed to Cameron.

180. During the '119 litigation, Professor Sangesland was deposed by Defendant Kvaerner as well as Cameron.

181. Much of Professor Sangesland's testimony directly refutes, or is inconsistent with, arguments of patentability made by Cameron during the prosecution of the '119 patent.

182. For example,[3] Cameron repeatedly argued during the prosecution of the '119 patent that the packing between the production tubing and the casing at the bottom

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3 The examples of Professor Sangesland's testimony that refutes Cameron's arguments to the USPTO that are set forth in this counterclaim are merely representative and should not be considered an exhaustive identification of Cameron's arguments that are refuted by Professor Sangesland's testimony. Numerous additional arguments made by Cameron during the prosecution of the '119 patent are refuted by Professor Sangesland's testimony.

of the tubing in Sangesland's prior art subsea tree would have precluded any circulation through the annulus between them.

183. Additionally, Cameron argued that none of the prior art, including a 1991 paper by Sangesland, disclosed the ability to circulate fluid from the tubing to the annulus because this packing would have been present.

184. Professor Sangesland testified, however, that an engineer of ordinary skill would have been aware of three standard techniques to accomplish such circulation: using a sliding-sleeve valve, using a "side-pocket mandrel," or simply making a hole in the tubing.

185. Moreover, Professor Sangesland also testified that the Hopper patents also do not disclose how fluid can flow from tubing to annulus if one assumes the presence of a production packer downhole.

186. As another example, Cameron also argued during the prosecution of the '119 patent that the tree described in Sangesland's 1991 paper could not circulate fluid from the BOP bore into the workover passageway as disclosed in the '119 patent.

187. Cameron argued that the workover line would necessarily contain a "stab" connection isolating that line from the BOP bore, which would have made circulation impossible.

188. Cameron also argued that this would have been necessary because part of the circulation path, the "completion riser," would have had two vertical bores that would require connection within the tree.

189. Professor Sangesland testified, however, that all of Cameron's assumptions were wrong.

190. Professor Sangesland testified that (i) the workover line was directly connected to the BOP bore, exactly as shown in a figure from his 1991 paper; (ii) the prior art tree employed a standard connection rather than a stab; and (iii) the "completion riser" was a simple pipe with only one vertical bore.

191. Further, Professor Sangesland repeatedly observed that there would have been no reason to employ a dual-bore riser on his prior art tree, which had only one vertical bore.

192. As another example, Cameron argued during the prosecution of the '119 patent that there would have been no motivation to add a second pressure barrier to Professor Sangesland's prior art tree design.

193. Cameron argued that Professor Sangesland's tree was designed for pumped (*i.e.*, low-pressure) wells and would not have been a suitable starting point for designing a tree for a positive-pressure well that would require a second barrier.

194. Professor Sangesland testified, however, that under the applicable standards in either Norway or the United Kingdom, there is no difference in barrier requirements between pumped and positive-pressure wells.

195. As these examples show, Professor Sangesland's testimony systematically refutes Cameron's attempts to distinguish its claimed horizontal tree from Professor Sangesland's prior art tree.

196. Because Professor Sangesland's testimony refutes, or is inconsistent with, Cameron's arguments of patentability made during the prosecution of the '119 patent, his testimony was material to the patentability of the claims of the '119 patent.

197. Despite this fact, Cameron failed to disclose any of Professor Sangesland's testimony to the USPTO during the prosecution of the '119 patent.

198. Upon information and belief, Cameron intentionally withheld Professor Sangesland's testimony from the USPTO with the intent to deceive the examiner into allowing the claims of the '119 patent.

199. Additionally, during the '119 litigation, information pertaining to a Britoil prior art patent was provided to Cameron.

200. The named inventor of the Britoil prior art patent was Peter Doyle.

201. Mr. Doyle was deposed by the parties during the '119 litigation.

202. During that deposition, Cameron's counsel questioned Mr. Doyle about Professor Sangesland's prior art documents.

203. During the prosecution of the '119 patent, Cameron submitted a portion of Mr. Doyle's testimony and mischaracterized that testimony in an effort to support its arguments regarding why Professor Sangesland's prior art tree was distinguishable from Cameron's claimed invention.

204. After having an opportunity to review Cameron's patentability arguments based on its mischaracterizations of his testimony, Mr. Doyle submitted a declaration to specifically address Cameron's misquotes and misrepresentations of his testimony.

205. The declaration of Mr. Doyle was provided to Cameron during the prosecution of the '119 patent.

206. Mr. Doyle's declaration refutes Cameron's attempts to rely on his testimony to distinguish its claimed horizontal tree from Professor Sangesland's prior art tree.

207. Because the statements in Mr. Doyle's declaration refute, or are inconsistent with, Cameron's arguments of patentability made during the prosecution of the '119 patent, his declaration was material to the patentability of the claims of the '119 patent.

208. Despite this fact, Cameron failed to submit Mr. Doyle's declaration to the USPTO during the prosecution of the '119 patent.

209. In fact, Cameron failed to submit Mr. Doyle's declaration even after the materiality of that declaration was pointed out by Defendant Kvaerner's counsel.

210. Upon information and belief, Cameron intentionally withheld Mr. Doyle's declaration from the USPTO with the intent to deceive the examiner into allowing the claims of the '119 patent.

E. Cameron's Withholding Of Material Information From The USPTO During The Prosecution Of the '119 and '008 Patents

211. Cameron's deceptive conduct before the USPTO is also evidenced by the fact that during the prosecution of the '119 and '008 patents, Cameron withheld the transcripts of Professor Sangesland's deposition testimony discussing his prior art subsea tree.

212. The Sangesland deposition transcripts are material to the patentability of the claims of the '119 and '008 patents for the reasons set forth in the preceding section.

213. Despite the materiality of Professor Sangesland's testimony, Cameron intentionally withheld the Sangesland deposition transcripts.

214. Cameron's conduct is intentionally deceptive in light of the fact that during the prosecution of the '119 and '008 patents, Cameron submitted other deposition transcripts from the '119 patent litigation.

215. Cameron failed to submit the Sangesland deposition transcripts even after Kvaerner's counsel sent Cameron's counsel a letter during the '119 litigation that specifically pointed out the materiality of Professor Sangesland's testimony and noted Cameron's failure to submit the Sangesland deposition transcripts.

216. Despite receiving this letter, Cameron still failed to submit the Sangesland deposition transcripts during the prosecutions of the '119 and '008 patents.

217. Cameron likewise failed to submit Kvaerner's counsel's letter to the USPTO during the prosecutions of the '119 and '008 patents.

218. Upon information and belief, Cameron intentionally withheld the Sangesland deposition transcripts and Kvaerner's counsel's letter during the prosecutions of the '119 and '008 patents with the intent to deceive the examiner into allowing the claims of the '119 and '008 patents.

F. <u>Cameron's Misrepresentations Regarding Documents From The '119 Patent Litigation During The Prosecution Of The '660 Patent</u>

219. Cameron's deceptive conduct before the USPTO is also reflected by misrepresentations Cameron made to the USPTO during the prosecution of the '660 patent concerning a prior claim construction ruling of the related '119 patent made by the United States District Court for the Southern District of Texas.

220. Specifically, during the '119 patent litigation, the Court construed certain claim terms of the '119 patent, including "spool tree."

221. The Court noted that the specification of the '119 patent (which is the same as the specification of the '660 patent) defines the invention as a "spool tree" excluding all internal valves, citing – *inter alia* – the following passage from the '119 patent's specification:

> Double barrier isolation, that is to say two barriers in series, are generally necessary for containing pressure in a well. ***If a spool tree is used instead of a conventional Christmas tree, there are no valves within the vertical production and annulus fluid flow bores within the tree***, and alternative provision must be made for sealing the bore or bores through the top of the spool tree which provide for wire line or drill pipe access. (Emphasis added).

222. Although Cameron argued during the '119 patent litigation that the specification of the '119 passage only meant that there were no permanent valves in the vertical bore of the spool tree, the court disagreed, concluding that the term "spool tree" meant "a tree having no internal valves," and concluding that "[t]he specification thus explicitly excludes valves within the spool tree."

223. During the prosecution of the '660 patent, Cameron pointed the USPTO examiner to the Court's claim construction opinion and order in the '119 patent litigation and argued:

> Applicant draws the Examiner's attention to pages 21-39 of the Memorandum and Order discussing the claim terms "spool tree" and "closure member." At the end of page 27, the Court "concludes that where a claim in the '119 patent elements place a closure member inside the "spool tree," the term "closure member" is restricted to exclude a valve because of the unequivocal definition of the invention in the specification as a "spool tree" excluding all valves. Applicant respectfully disagrees with this interpretation of these claim elements and to avoid this ambiguity in the future, has added new claims in the present application using other terms which are not intended to be so limited, i.e., ***the subsea tree of the present invention may include internal valves***.

224. Notwithstanding the fact that the emphasized portion of the quoted passage is a totally self-serving statement that was unnecessary to overcome any rejection by the examiner, the "other terms" that Cameron references still refer to a "spool tree" and, thus, do not somehow change the Court's claim construction ruling to permit the use of internal valves in the claimed subsea tree.

225. Additionally, the passage above shows that Cameron referenced the Court's claim construction when it suited Cameron's purpose of making an unnecessary, self-serving statement about the meaning of the Court's claim construction.

226. However, when Cameron should have discussed the Court's claim construction in response to a rejection made by the examiner, Cameron did not mention the Court's claim construction.

227. Such conduct was intentionally misleading.

228. Specifically, at a later stage during the prosecution of the '660 patent, the USPTO examiner made the following rejection:

> Claims 57 . . . are rejected under 35 U.S.C. § 112, second paragraph, as being incomplete for omitting essential elements, such omission amounting to a gap between the elements. See MPEP § 2172.01. The omitted elements are: The ***flowpath externally*** of the spool tree 34 that selectively connects the work-over port/passage 73 and the annulus port/passage 64. Without this flowpath and the ***valves therein***, fluid cannot be circulated in the manner as recited or a "loop line" cannot be formed as recited.

229. In response, Cameron argued that an external flowpath was not an essential element, but only one embodiment.

230. Cameron further argued:

> Applicant refers the examiner to the Memorandum and Order of the United States District Court for the Southern District of Texas dated February 19, 1999; the Opinion of the United States Court of Appeals for the Federal Circuit dated May 14, 2002; and the Findings of Fact, Conclusions of Law, and Order of Stanley J. Roszkowski, Arbitrator, dated January 25, 2005, which state that ***the annulus and workover valves may be internal to the spool tree body and do not have to be external of the spool tree body***. Thus, if the annulus and workover valves may be internal of the spool body, then the circulation path may be internal also.

231. Revealingly, the list of orders cited by Cameron does not include the Court's claim construction order from the '119 patent litigation, an order that directly

contradicts the statement made by Cameron to the examiner (*i.e.*, the Court's claim construction order requires that the annulus and workover valves cannot be internal valves).

232. More importantly, Cameron's statement is completely false.

233. The three documents referenced by Cameron ((1) the February 19, 1999 Memorandum and Order from the '119 patent litigation; (2) the May 14, 2002 Federal Circuit Opinion; and (3) the January 25, 2005 Findings and Order of Arbitrator Stanley J. Roszkowski) do not state that the annulus and workover valves may be internal to the spool body.

234. As such, Cameron intentionally misrepresented the content of the referenced documents.

235. Because Cameron's statement was made to overcome an examiner's rejection, the statement is material to the patentability of one or more claims of the '660 patent.

236. Upon information and belief, Cameron made the misrepresentation with the intent to deceive the examiner into allowing one or more claims of the '660 patent.

G. <u>Cameron's Withholding of Material Information And Misrepresentations Regarding The Prior Art During the Prosecution Of The '039 Patent</u>

237. Cameron's fraudulent and deceptive conduct before the USPTO is also evidenced by the fact that during the prosecution of the '039 patent, Cameron withheld the Declaration of Michael Capesius and the January 8, 2003 sworn Deposition Upon Written Questions of Peter A. Scott.

238. Specifically, during the prosecution of the European equivalent of one of the Hopper patents, a hearing was conducted relating to the opposition of the Hopper

patent by two opposers, one of which was Kvaerner. The hearing was conducted on June 29, 2005 before the Opposition Division of the European Patent Office in Munich, Germany. The minutes of the hearing reflect that David Rose, one of the attorneys representing Cameron before the USPTO in the prosecution of the '039 patent, was present at the hearing and had access to the documents and evidence presented at the hearing.

239. After the hearing, Mr. Rose submitted the Decision Rejecting The Opposition (see reference AA) and the Minutes of the oral proceedings before the Opposition Division dated 08/05/2005 (see reference AB) to the USPTO. As confirmed by the two documents that Mr. Rose did submit to the USPTO, there were several documents containing material information that were submitted during the European Opposition, but withheld from the USPTO by Mr. Rose. The withheld documents include the Declaration of Michael Capesius and attached SISL and Sangesland references and the January 8, 2003 sworn Deposition Upon Written Questions of Peter A. Scott and attached Exhibits (the SISL Reports).

240. On November 30, 2004, the USPTO examiner issued an Office Action in the prosecution of the '039 patent in which, *inter alia*, all of the pending claims were rejected as being anticipated by one of the SISL Reports (Subsea Submersible Pumping – Second Interim Report – Technical June 1991).

241. In response to the examiner's rejection, Cameron, through its counsel Mr. Rose, attacked the SISL Second Interim Report by arguing that the document was "Not Prior Art" because allegedly it was confidential, was not publicly available, and lacked

authentication. Cameron made no effort to distinguish its pending claims from the disclosure of the SISL document.

242. On June 30, 2005, the USPTO examiner once again rejected all of the pending claims in the '039 patent as being anticipated by the prior art. However, instead of relying on the SISL Second Interim Report, the examiner cited a different SISL report, the January 1991 Conceptual Design Report Task Series 2000. Apparently, even though the examiner did not believe Cameron's arguments regarding publication, confidentiality, and authenticity to be correct, he felt it more advisable to use a different, earlier SISL Report.

243. On August 30, 2005, two months after the hearing on the European Opposition, Cameron submitted two self-serving documents from the European hearing, the Decision and the Minutes of the Oral Proceedings. What Cameron elected not to provide to the USPTO from the European Opposition, despite their indisputable materiality, were the Declaration of Michael Capesius and attached SISL and Sangesland references, and the January 8, 2003 sworn Deposition Upon Written Questions of Peter A. Scott and attached Exhibits (the SISL Reports). Both of the withheld documents, together with the attachments thereto, provide credible evidence that is directly contrary to the arguments made by Cameron to gain allowance of claims in the '039 patent. Both of these documents and the attachments were known to one or more of the individuals representing Cameron before the USPTO during the prosecution of the '039 patent.

244. In response to the examiner's second rejection, this one based on a different, earlier SISL Report, Cameron again argued that the SISL reference was "Not Prior Art" because allegedly it was confidential and not a publication. However,

Cameron did not argue that the second SISL reference was not authentic. Presumably the reason that Cameron withheld this argument is that it was in possession of the Peter Scott Deposition Upon Written Questions, which authenticated all of the SISL Reports. Once again, Cameron did not submit any arguments attempting to distinguish its pending claims, which the examiner stated were anticipated by either of the SISL references. Cameron intentionally failed to provide this known material information to the USPTO examiner and thereby induced the examiner to allow claims over anticipatory SISL references.

245. In an October 5, 2005 advisory action allowing most of the pending claims, the examiner acknowledged that the anticipation rejection was withdrawn based on Cameron's arguments regarding the SISL references not being prior art. If the examiner had been provided with the Capesius Declaration and the Peter Scott Deposition Upon Written Questions, he could not have allowed the claims in the form in which they were issued.

246. The issuance of the '039 patent was solely the result of the intentional withholding of material prior art by Cameron and was based on Cameron's deliberate misrepresentation of the legal status of the cited prior art. During the prosecution of the '039 patent Cameron was in possession of material documents and information that were in direct contrast to the arguments it presented to the USPTO and that it intentionally withheld from consideration by the USPTO in evaluating its claims.

247. Accordingly, based on the preceding bases, Dril-Quip seeks a declaratory judgment pursuant to 28 U.S.C. §§ 2201-2202 that the '945 patent, the '660 patent, the '039 patent, the '008 patent, the '119 patent, and the '707 patent are all unenforceable.

Count 4: Attorneys Fees and Costs

248. Dril-Quip incorporates by reference each preceding allegation as though expressly stated herein.

249. Dril-Quip is entitled to a declaration that this is an "exceptional" case within the meaning of 35 U.S.C. § 285, entitling Dril-Quip to an award of its reasonable and necessary attorneys' fees, expenses, and costs incurred in this action.

JURY DEMAND

250. Dril-Quip demands trial by a jury.

PRAYER FOR RELIEF

WHEREFORE, Defendant/Counter-Plaintiff Dril-Quip prays for the following relief:

(a) a declaration and judgment that U.S. Patent No. 7,117,945 is invalid, unenforceable, and/or not infringed by Dril-Quip;

(b) a declaration and judgment that U.S. Patent No. 6,991,039 is invalid, unenforceable, and/or not infringed by Dril-Quip;

(c) a declaration and judgment that U.S. Patent No. 7,093,660 is invalid, unenforceable, and/or not infringed by Dril-Quip;

(d) a declaration and judgment that U.S. Patent No. 6,547,008 is invalid, unenforceable, and/or not infringed by Dril-Quip;

(e) a declaration and judgment that U.S. Patent No. 6,039,119 is invalid, unenforceable, and/or not infringed by Dril-Quip;

(f) a declaration and judgment that U.S. Patent No. 5,547,707 is invalid, unenforceable, and/or not infringed by Drii-Quip;

(g) a declaration and judgment that this case is exceptional within the meaning of 35 U.S.C. § 285;

(h) an award of reasonable attorneys' fees and costs incurred by Dril-Quip in this action; and

(i) such other and further relief as this Court deems just and proper.

Respectfully submitted,

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DATED: April 4, 2007

787417 / 31110

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

CERTIFICATE OF SERVICE

I, Richard L. Horwitz, hereby certify that on April 4, 2007, the attached document was hand-delivered and was electronically filed with the Clerk of the Court using CM/ECF which will send notification of such filing(s) to the following persons and the document is available for viewing and downloading from CM/ECF:

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EXHIBIT A

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United States Patent [19]

Hopper et al.

[11] **Patent Number: 5,544,707**

[45] **Date of Patent: Aug. 13, 1996**

[54] **WELLHEAD**

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[73] Assignee: **Cooper Cameron Corporation**, Houston, Tex.

[21] Appl. No.: **204,397**

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[86] PCT No.: **PCT/US93/05246**

§ 371 Date: **Mar. 16, 1994**

§ 102(e) Date: **Mar. 16, 1994**

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PCT Pub. Date: **Dec. 9, 1993**

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Jun. 1, 1992 [EP] European Pat. Off. 92305014

[51] **Int. Cl.**[6] **E21B 33/03**

[52] **U.S. Cl.** **166/382**; 166/368

[58] **Field of Search** 166/348, 339, 166/368, 341, 347, 382, 88, 89, 95, 208

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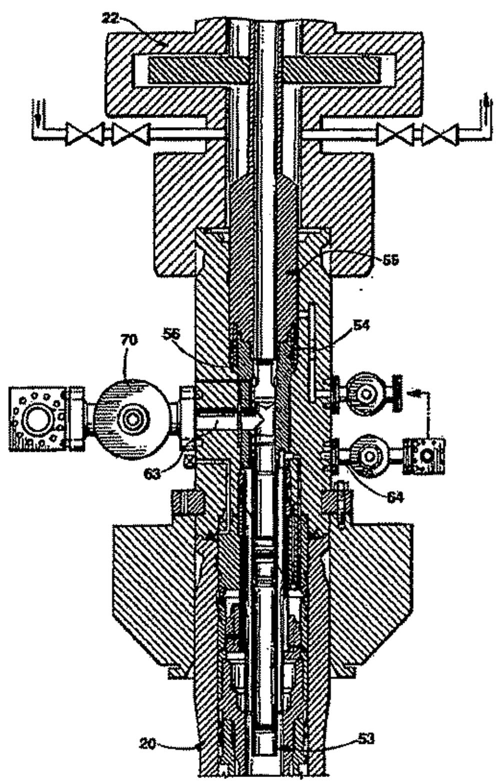
Primary Examiner—Hoang C. Dang
Attorney, Agent, or Firm—Conley, Rose & Tayon

[57] **ABSTRACT**

A wellhead having, instead of a conventional Christmas tree, a spool tree in which a tubing hanger is landed at a predetermined angular orientation. The tubing string can be pulled without disturbing the tree and access may be had to the production casing hanger for monitoring production casing annulus pressure and for the introduction of larger tools into the well hole without breaching the integrity of the well. In the embodiment described, a valve is used to open and close a fluid pressure passage between the production casing annulus and a production casing annulus monitoring port in the spool tree.

13 Claims, 16 Drawing Sheets



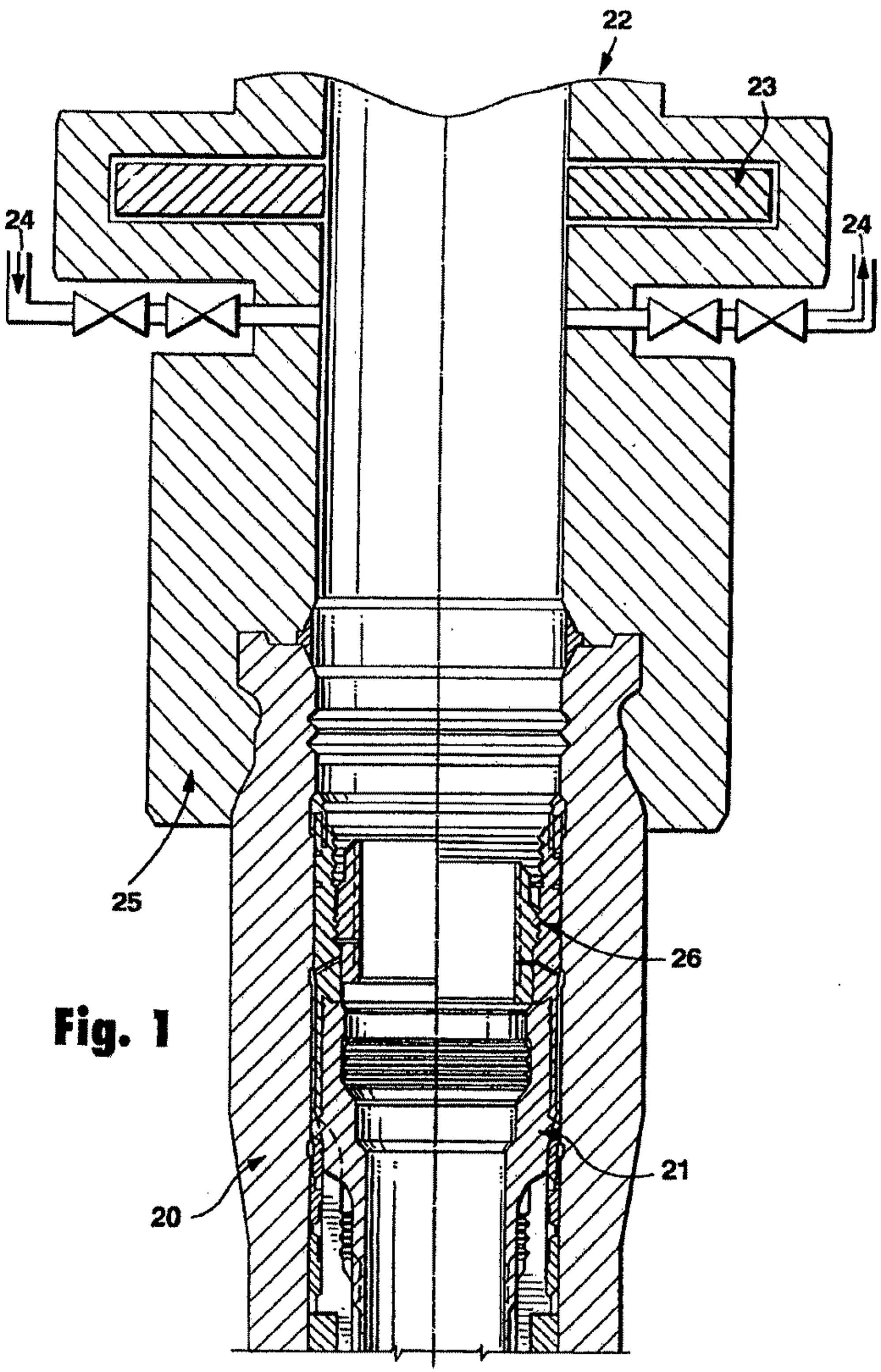


Fig. 1

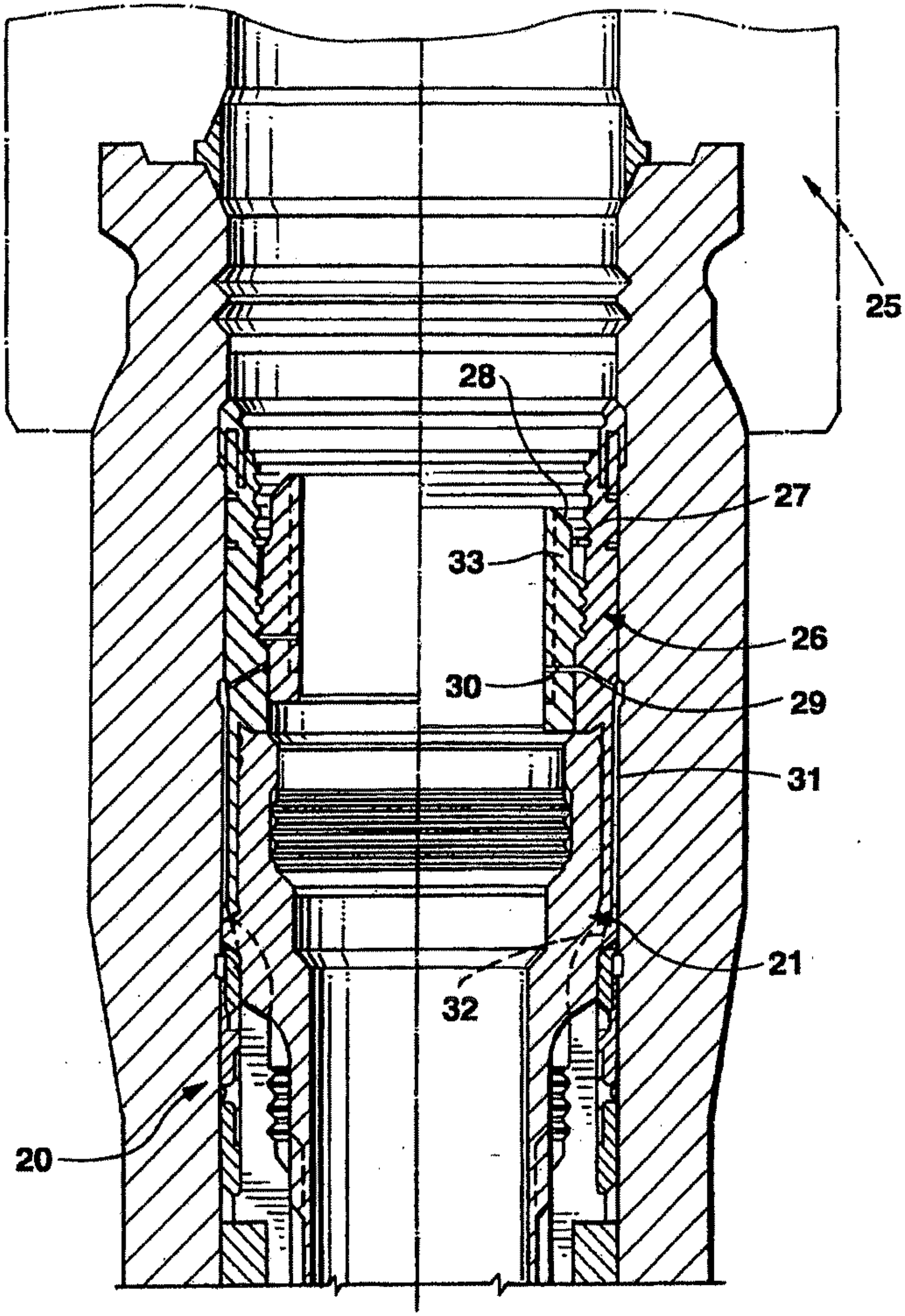
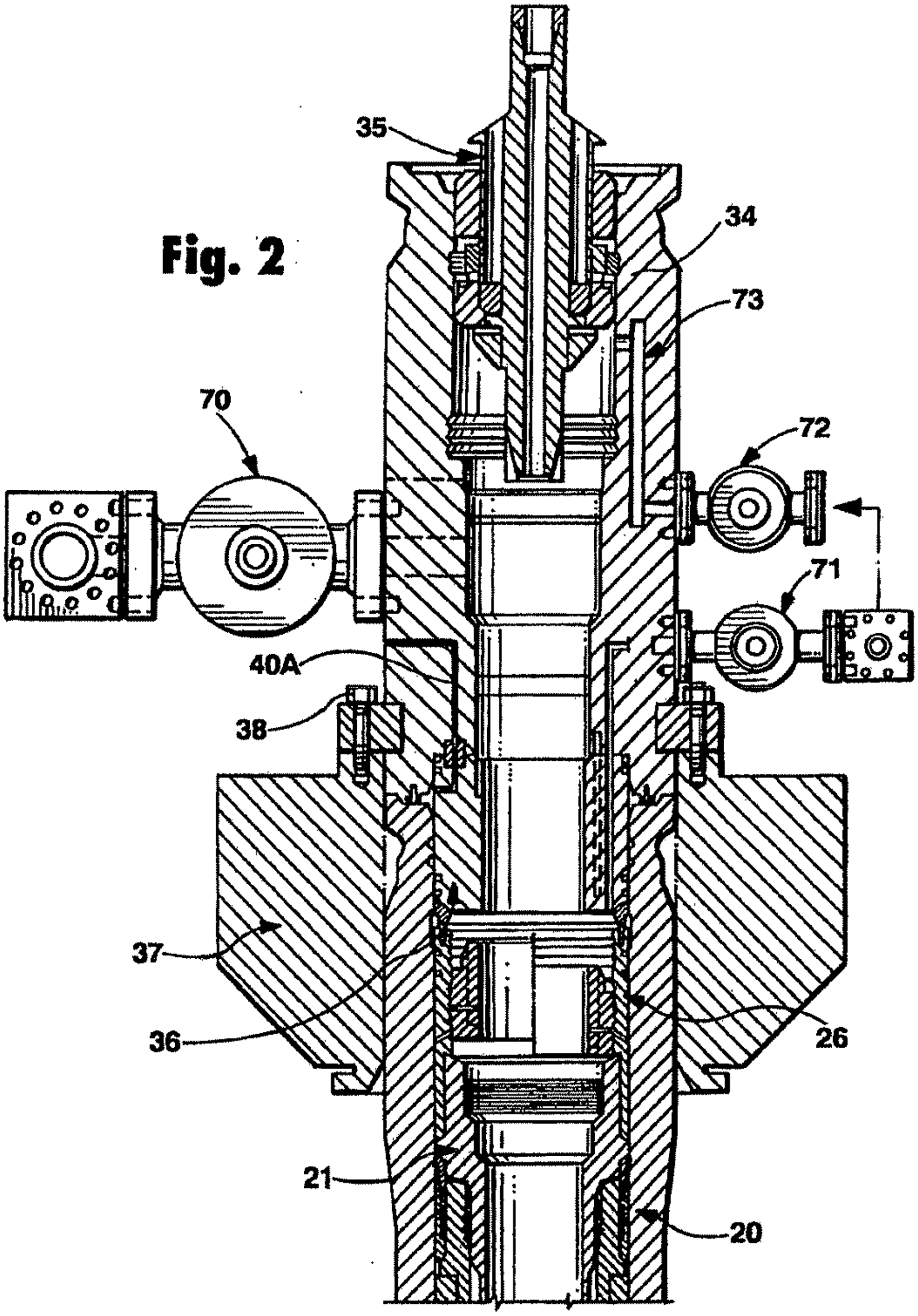


Fig. 1A

Fig. 2



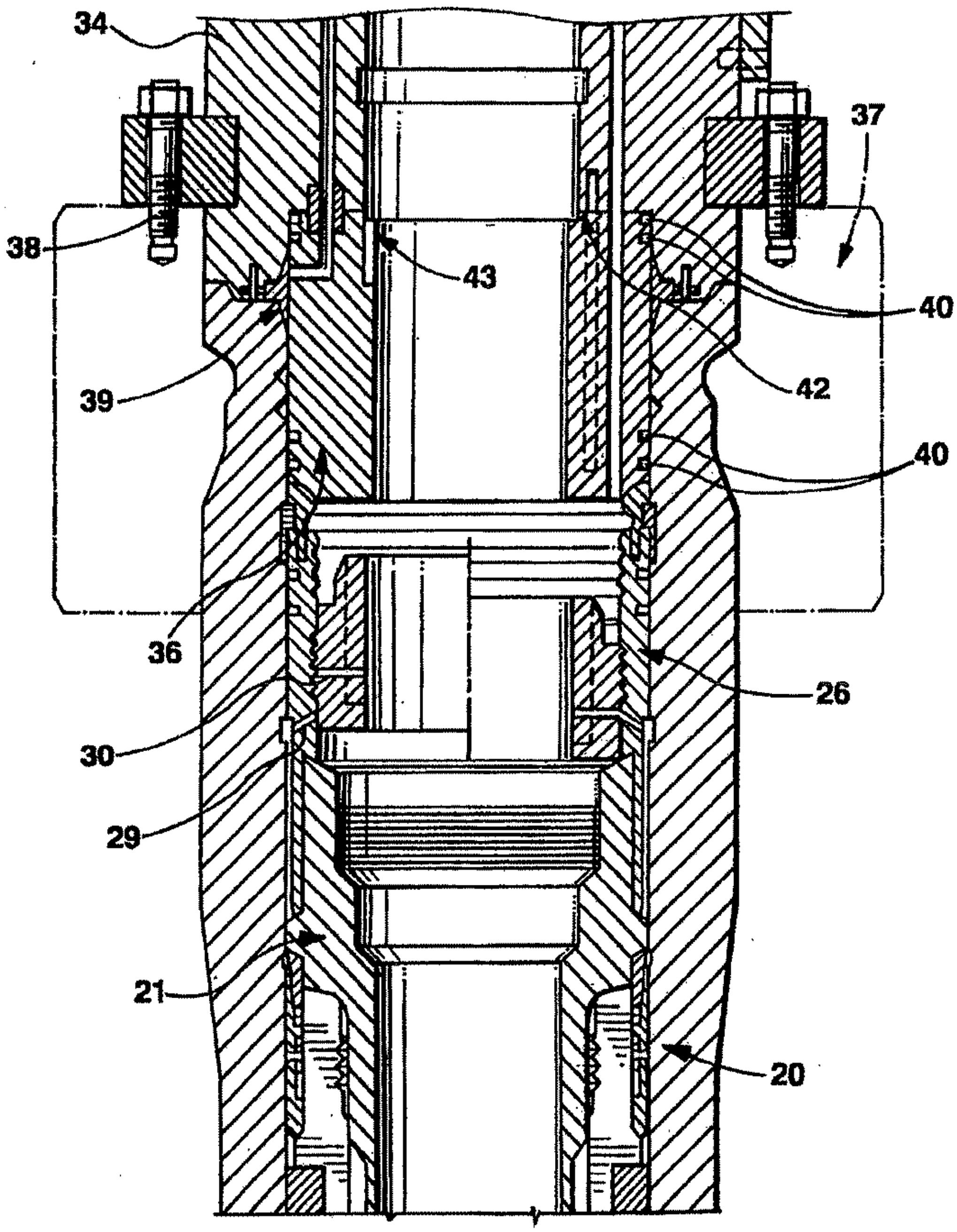


Fig. 2A

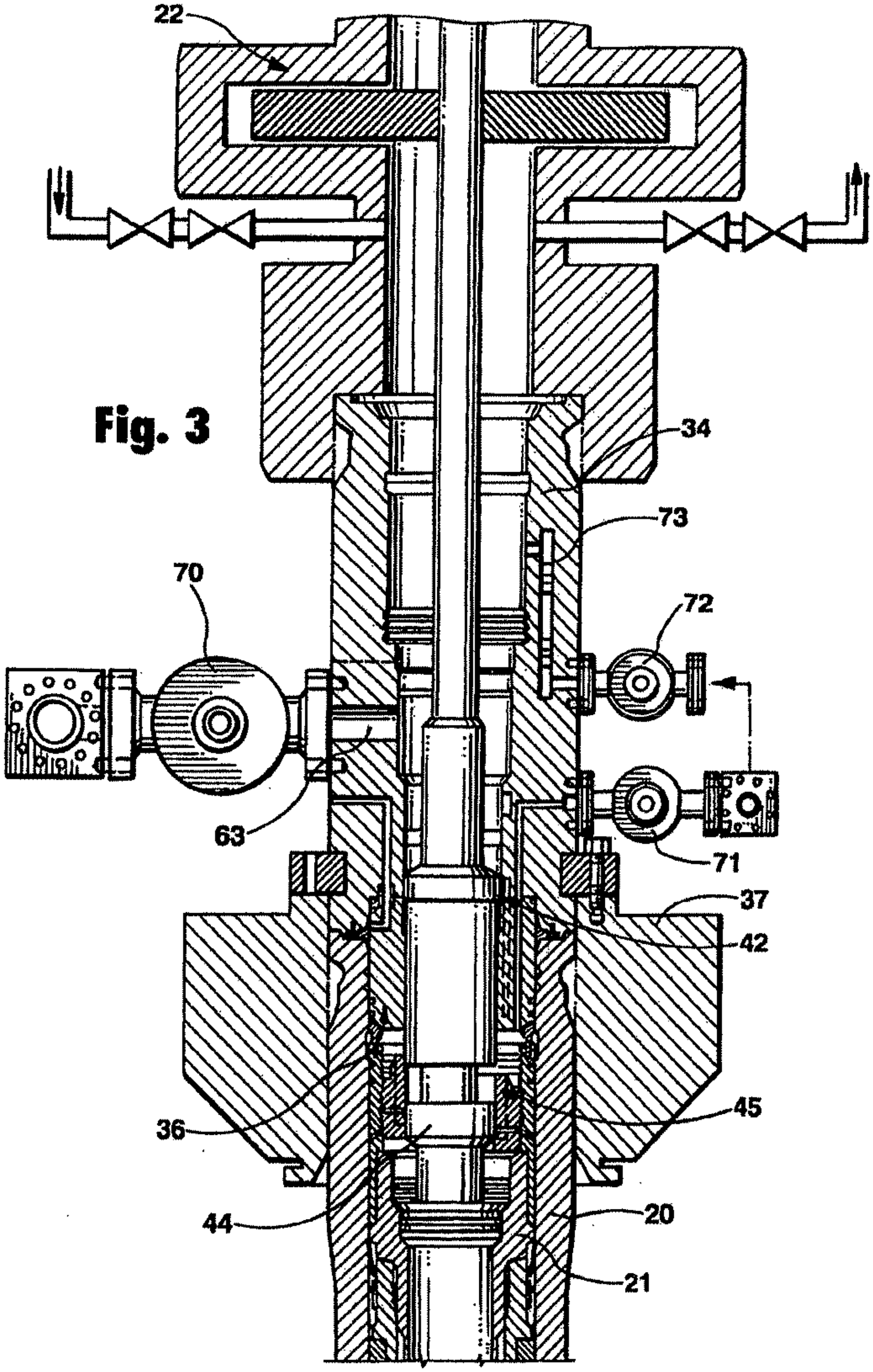


Fig. 3

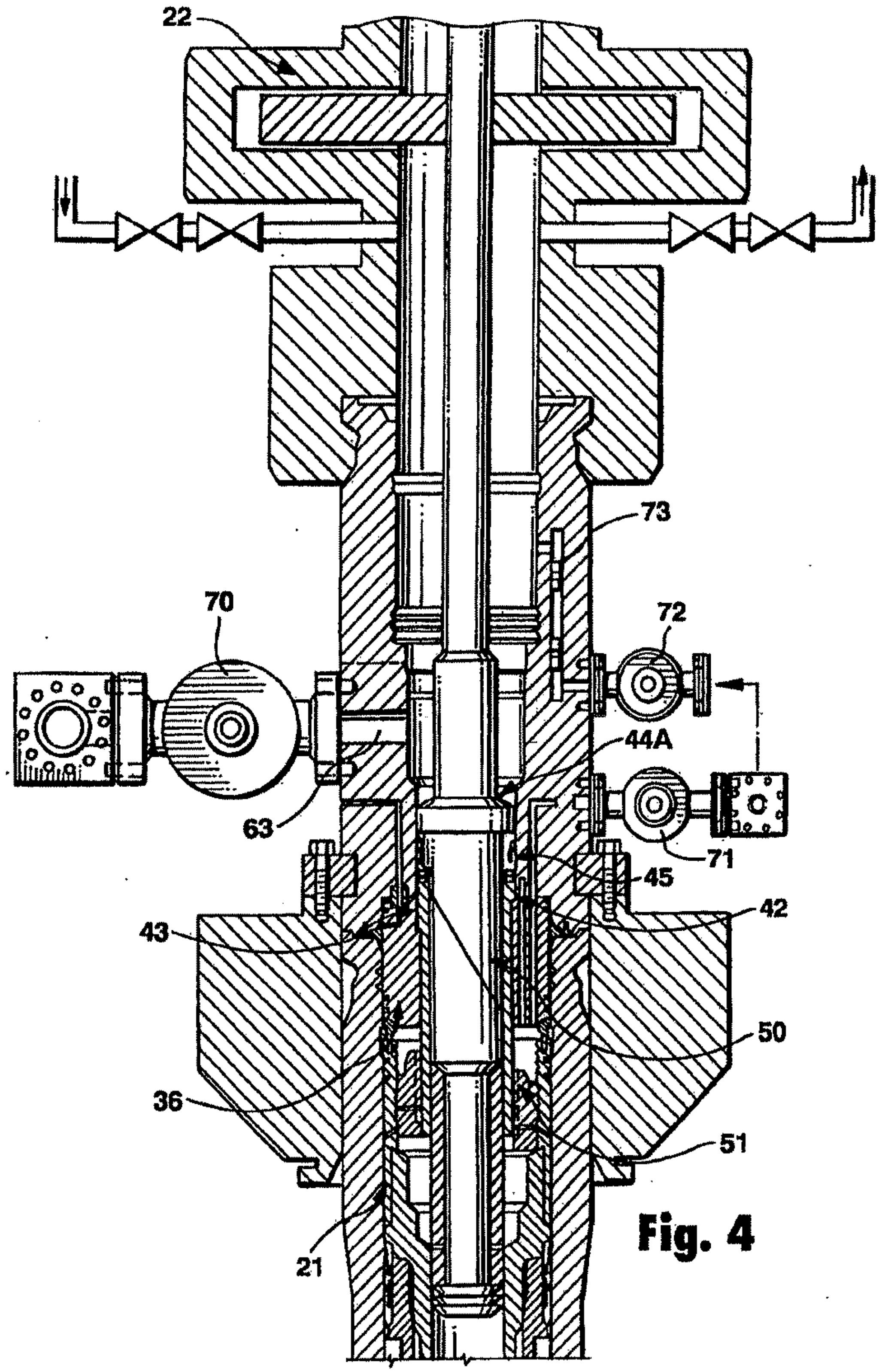
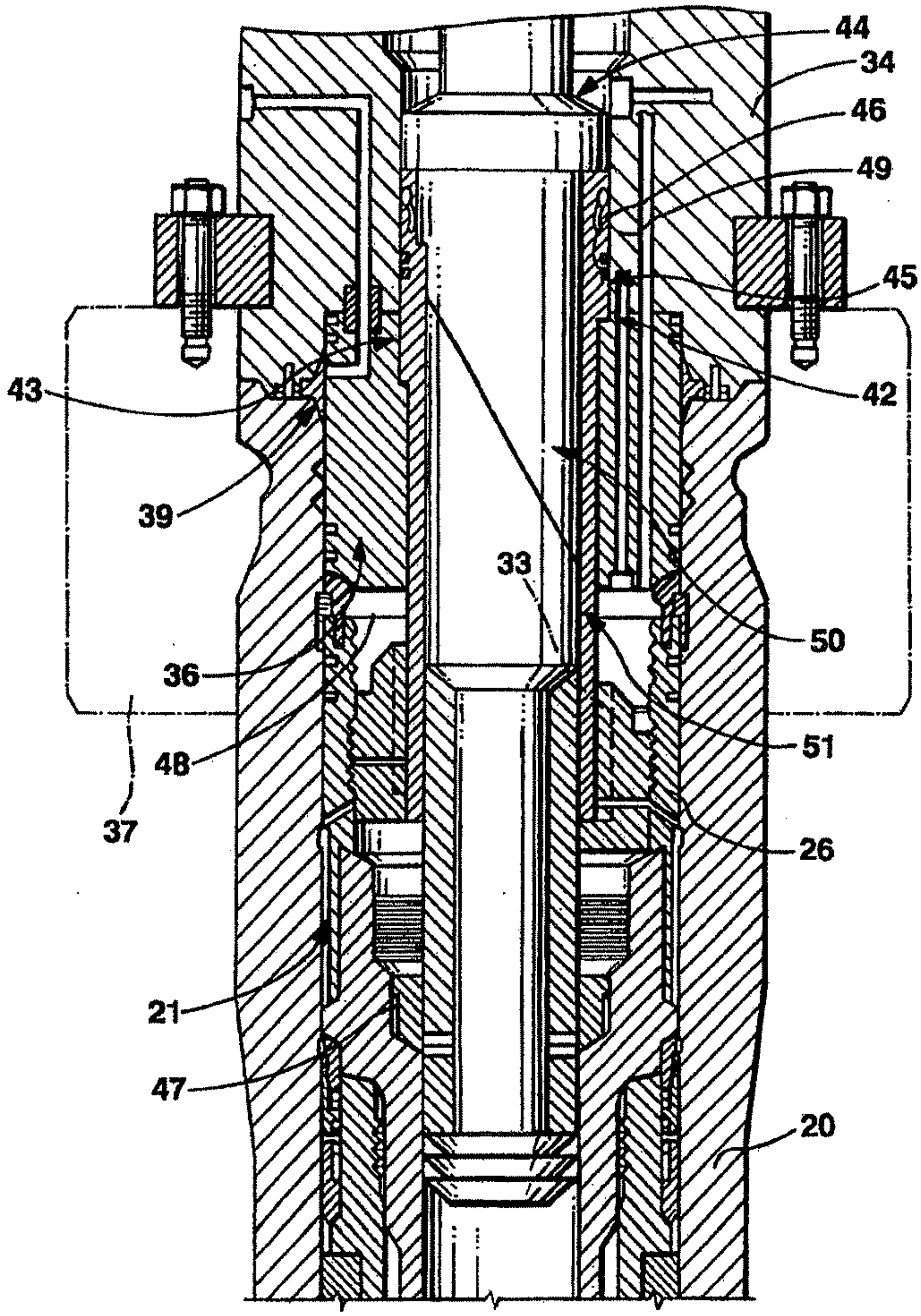


Fig. 4

Fig. 4A



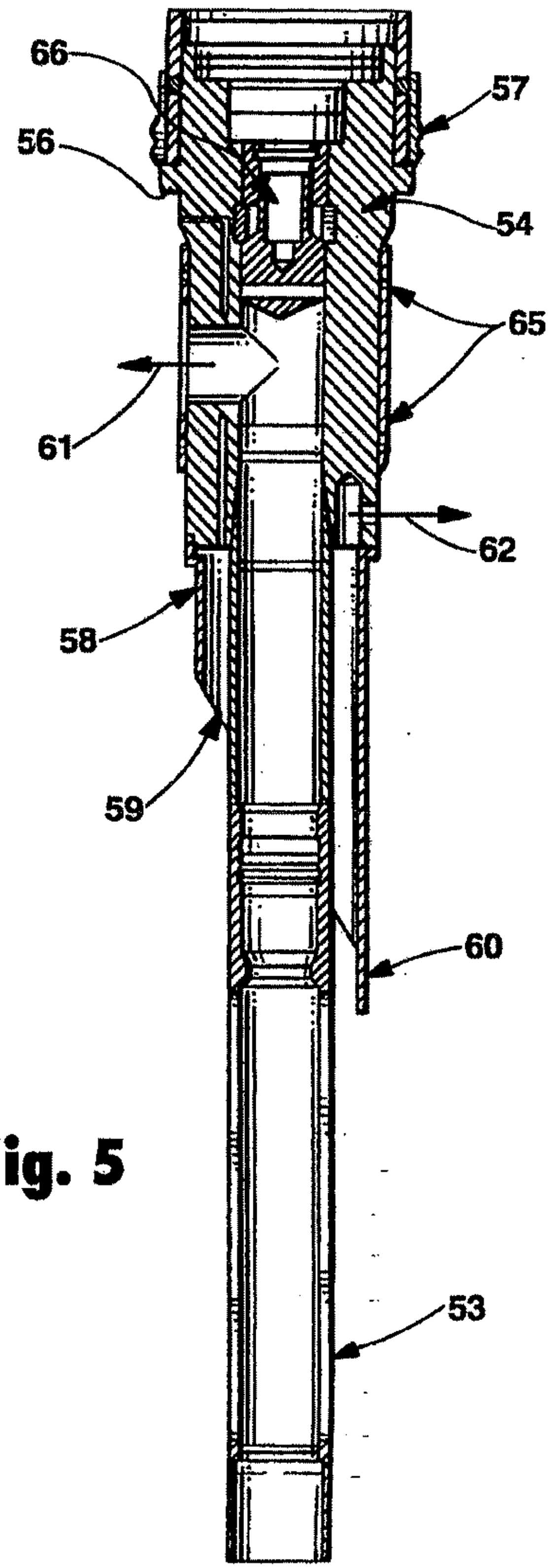


Fig. 5

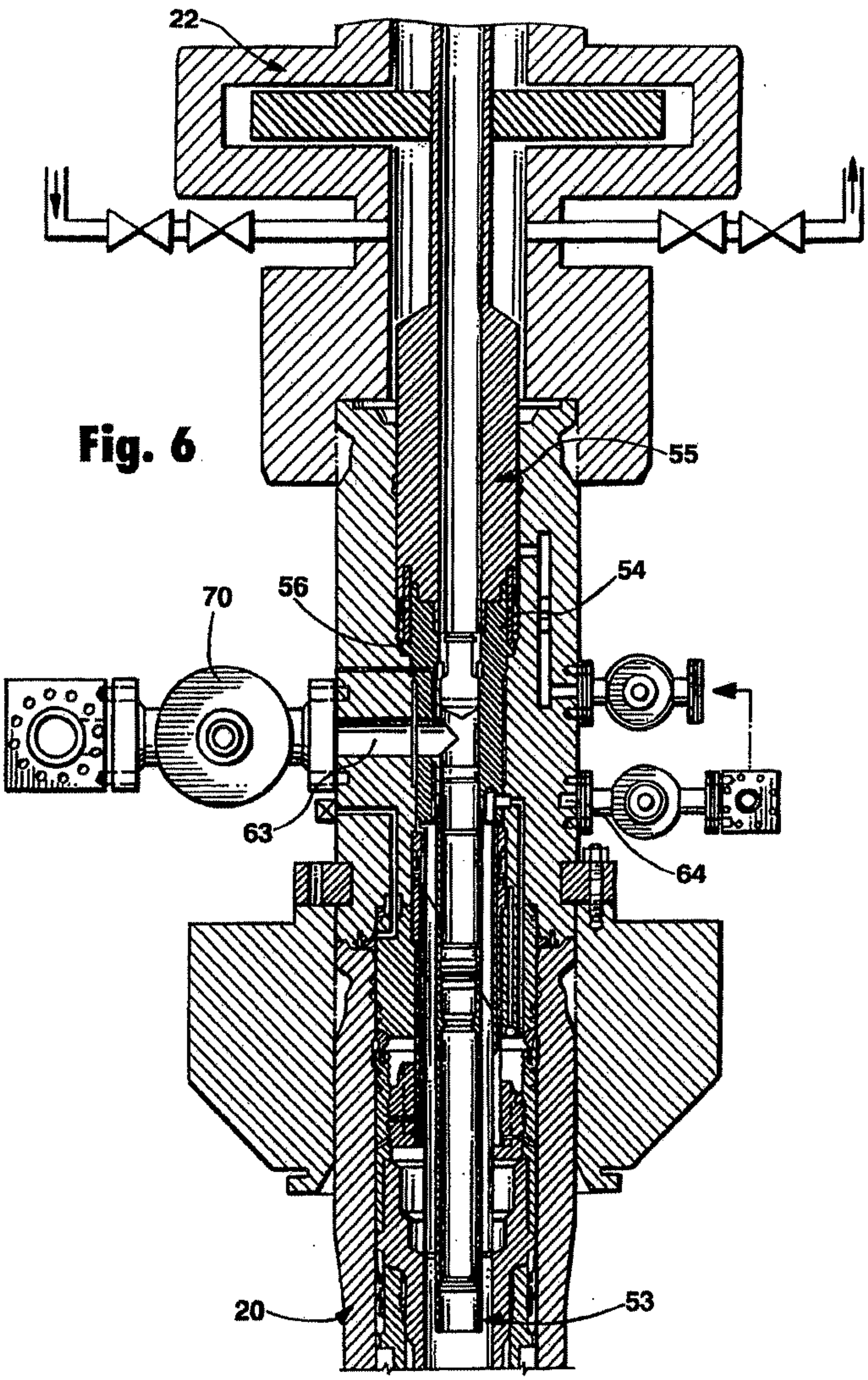


Fig. 6

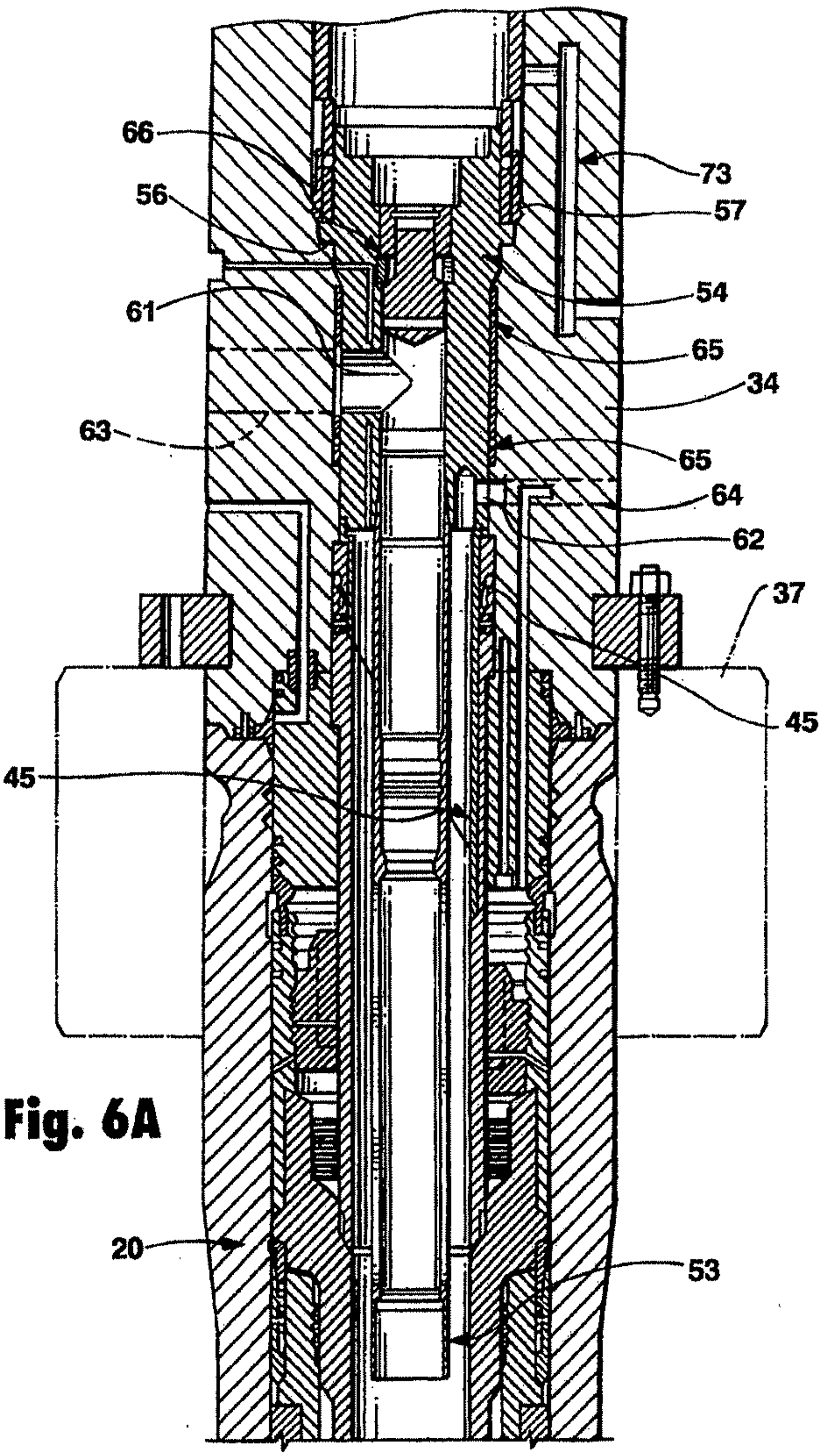


Fig. 6A

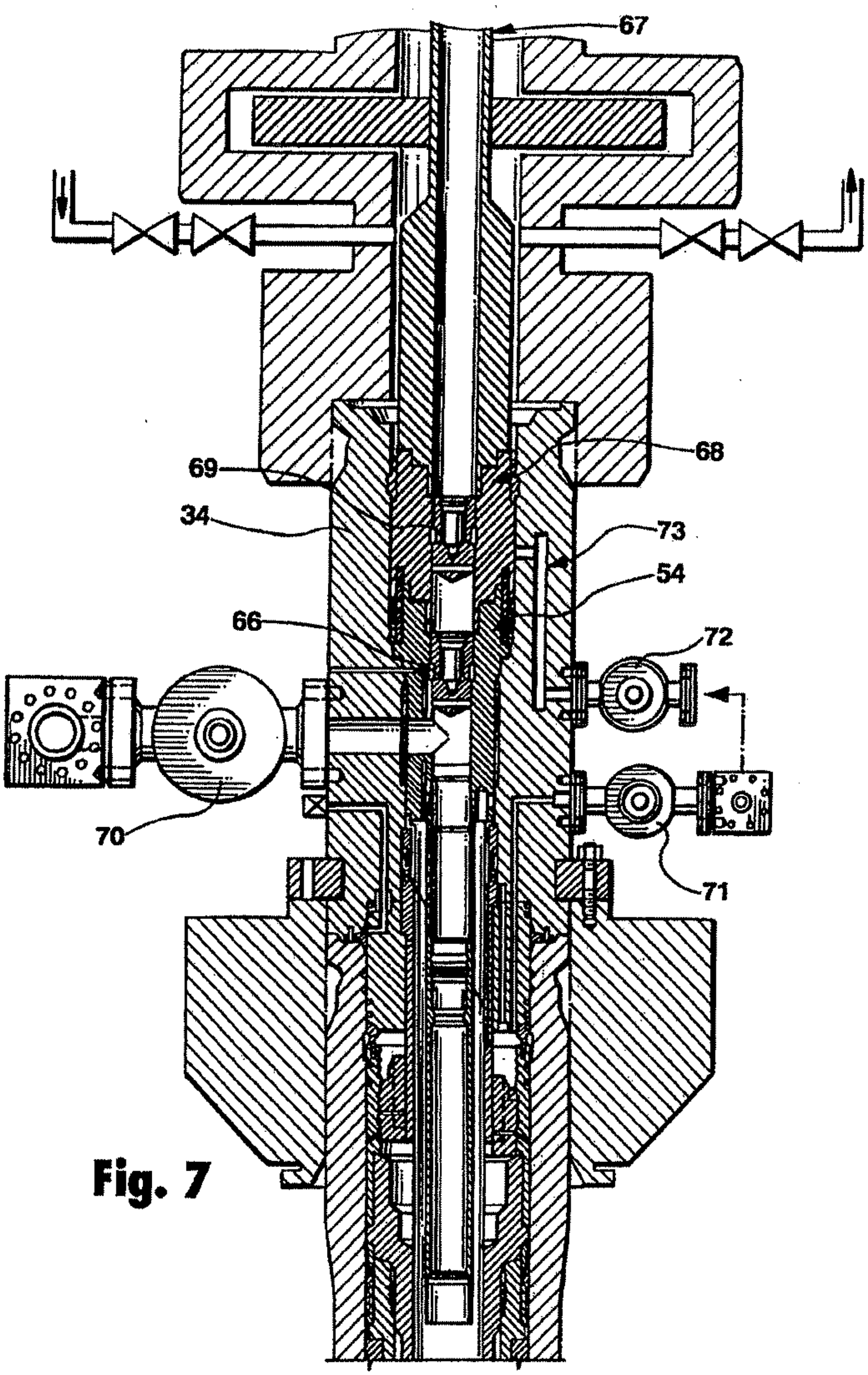


Fig. 7

Fig. 8

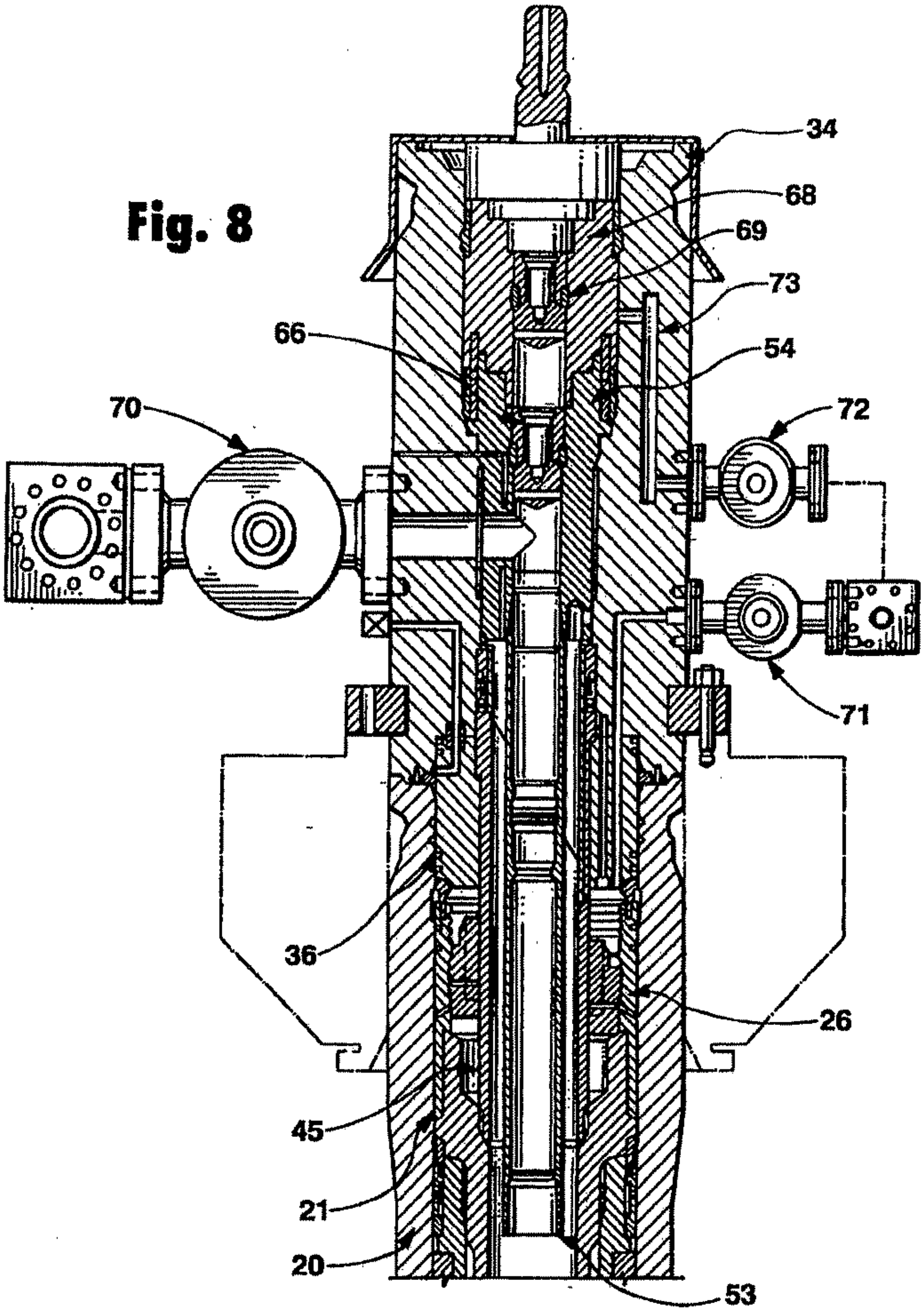


Fig. 9

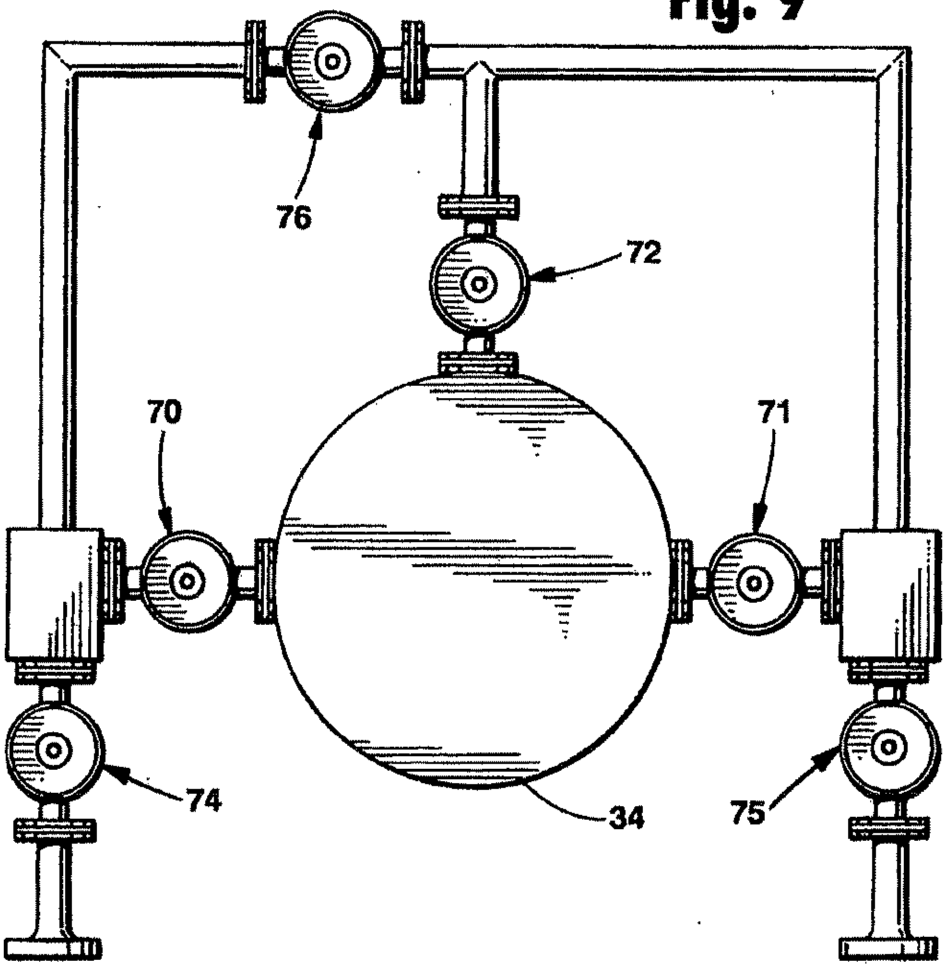


Fig. 13

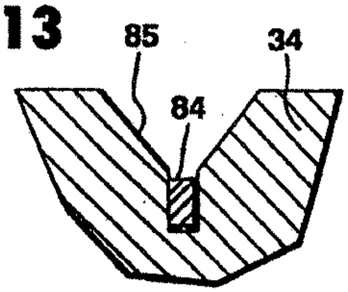


Fig. 13A

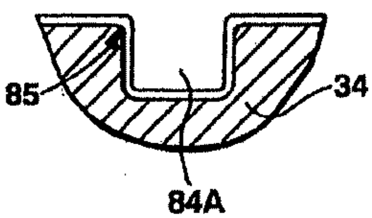


Fig. 13B

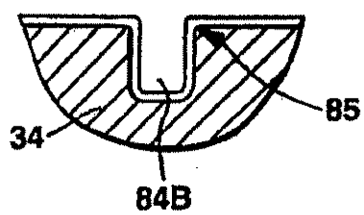
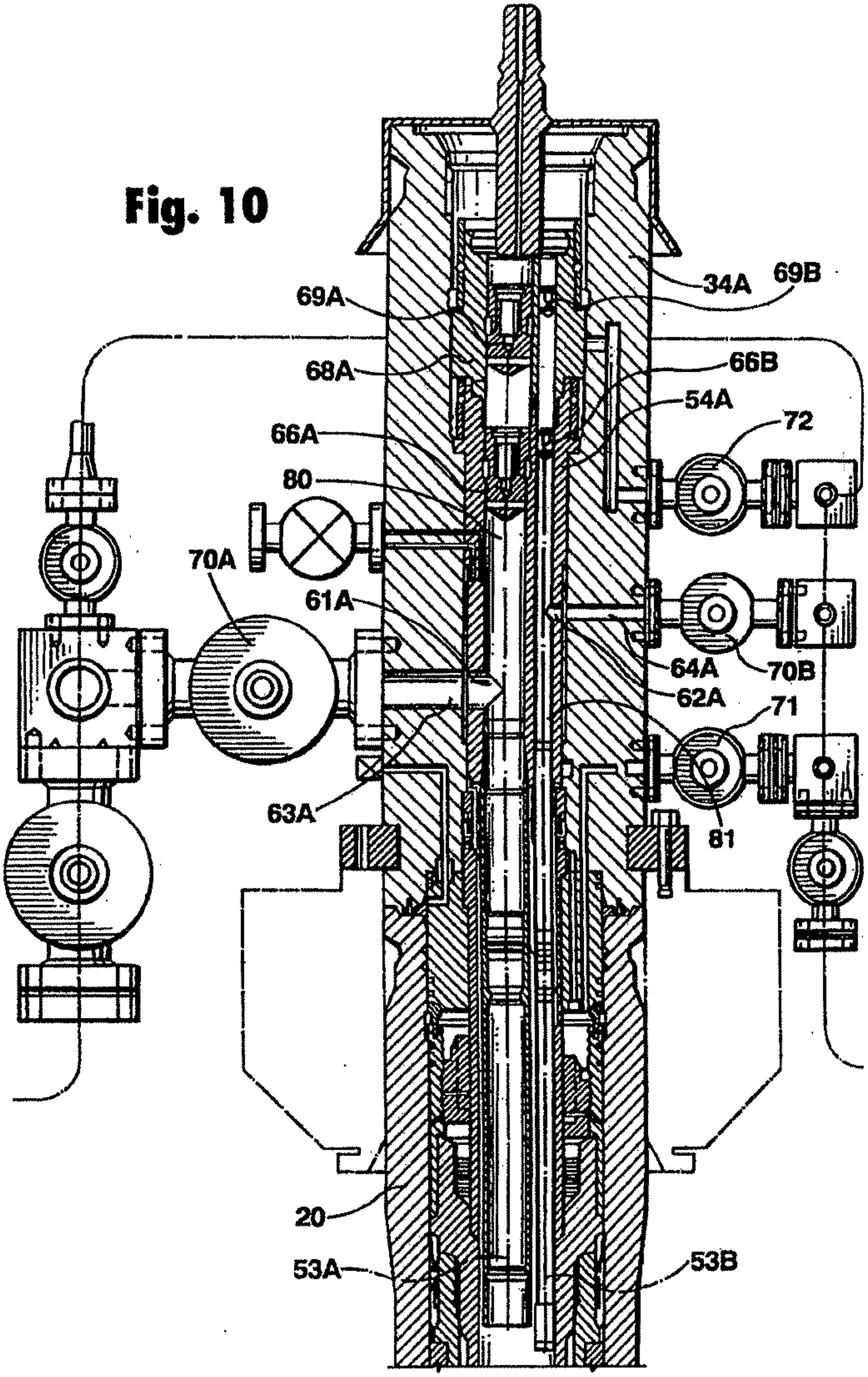


Fig. 10



34A
69B
69A
68A
66B
54A
72
66A
80
70A
61A
64A
70B
62A
71
63A
81
20
53A
53B

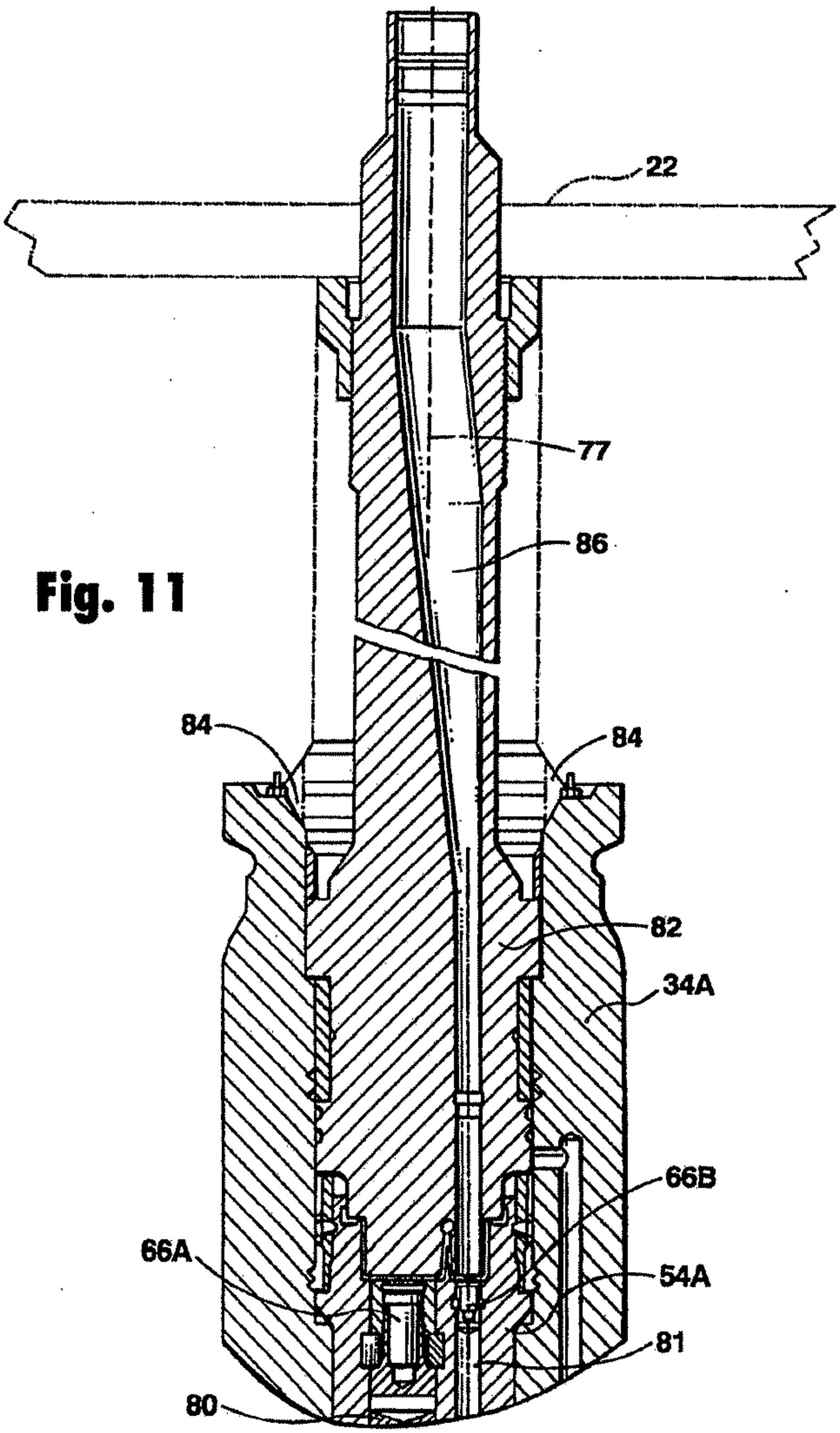


Fig. 11

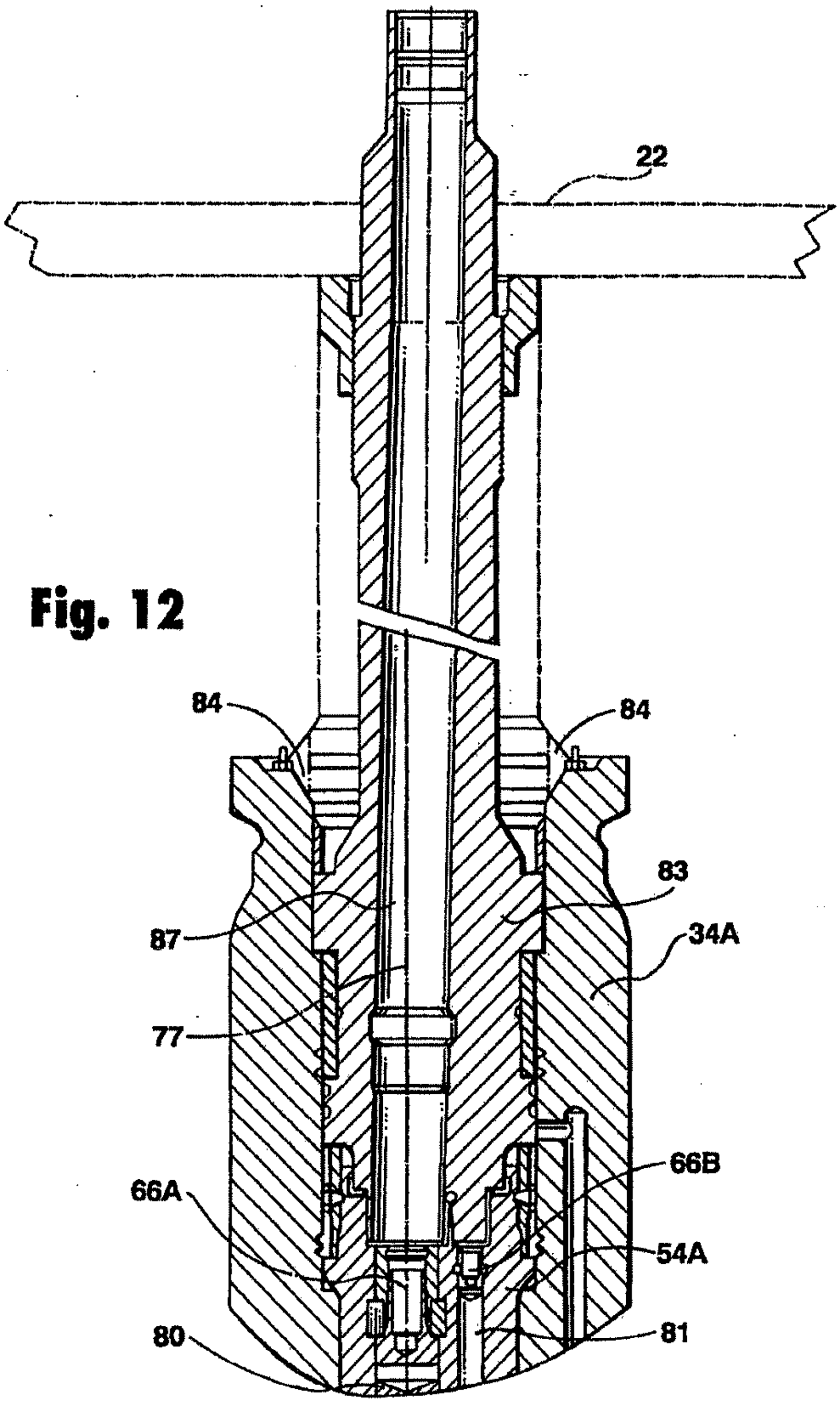


Fig. 12

WELLHEAD

BACKGROUND OF THE INVENTION

Conventionally, wells in oil and gas fields are built up by establishing a wellhead housing, and with a drilling blow out preventer stack (BOP) installed, drilling down to produce the well hole whilst successively installing concentric casing strings, which are cemented at the lower ends and sealed with mechanical seal assemblies at their upper ends. In order to convert the cased well for production, a tubing string is run in through the BOP and a hanger at its upper end landed in the wellhead. Thereafter the drilling BOP stack is removed and replaced by a Christmas tree having one or more production bores containing actuated valves and extending vertically to respective lateral production fluid outlet ports in the wall of the Christmas tree.

This arrangement has involved problems which have, previously, been accepted as inevitable. Thus any operations down hole have been limited to tooling which can pass through the production bore, which is usually no more than five inch diameter, unless the Christmas tree is first removed and replaced by a BOP stack. However this involves setting plugs or valves, which may be unreliable by not having been used for a long time, down hole. The well is in a vulnerable condition whilst the Christmas tree and BOP stack are being exchanged and neither one is in position, which is a lengthy operation. Also, if it is necessary to pull the completion, consisting essentially of the tubing string on its hanger, the Christmas tree must first be removed and replaced by a BOP stack. This usually involves plugging and/or killing the well.

A further difficulty which exists, particularly with subsea wells, is in providing the proper angular alignment between the various functions, such as fluid flow bores, and electrical and hydraulic lines, when the wellhead equipment, including the tubing hanger, Christmas tree, BOP stack and emergency disconnect devices are stacked up. Exact alignment is necessary if clean connections are to be made without damage as the devices are lowered into engagement with one another. This problem is exacerbated in the case of subsea wells as the various devices which are to be stacked up are run down onto guide posts or a guide funnel projecting upwardly from a guide base. The post receptacles which ride down on to the guide posts or the entry guide into the funnel do so with appreciable clearance. This clearance inevitably introduces some uncertainty in alignment and the aggregate misalignment when multiple devices are stacked, can be unacceptably large. Also the exact orientation will depend upon the precise positions of the posts or keys on a particular guide base and the guides on a particular running tool or BOP stack and these will vary significantly from one to another. Consequently it is preferable to ensure that the same running tools or BOP stack are used for the same wellhead, or a new tool or stack may have to be specially modified for a particular wellhead. Further misalignments can arise from the manner in which the guide base is bolted to the conductor casing of the wellhead.

SUMMARY OF THE INVENTION

In accordance with the present invention, a wellhead comprises a wellhead housing; a spool tree fixed and sealed to the housing, and having at least a lateral production fluid outlet port connected to an actuated valve; and a tubing hanger landed within the spool tree at a predetermined angular position at which a lateral production fluid outlet port in the tubing hanger is in alignment with that in the spool tree.

With this arrangement, the spool tree, takes the place of a conventional Christmas tree but differs therefrom in having a comparatively large vertical through bore without any internal valves and at least large enough to accommodate the tubing completion. The advantages which are derived from the use of such spool tree are remarkable, in respect to safety and operational benefits.

Thus, in workover situations the completion, consisting essentially of the tubing string, can be pulled through a BOP stack, without disturbing the spool tree and hence the pressure integrity of the well, whereafter full production casing drift access is provided to the well through the large bore in the spool tree. The BOP can be any appropriate workover BOP or drilling BOP of opportunity and does not have to be one specially set up for that well.

Preferably, there are complementary guide means on the tubing hanger and spool tree to rotate the tubing hanger into the predetermined angular position relatively to the spool tree as the tubing hanger is lowered on to its landing. With this feature the spool tree can be landed at any angular orientation onto the wellhead housing and the guide means ensures that the tubing string will rotate directly to exactly the correct angular orientation relatively to the spool tree quite independently of any outside influence. The guide means to control rotation of the tubing hanger into the predetermined angular orientation relatively to the spool tree maybe provided by complementary oblique edge surfaces one facing downwardly on an orientation sleeve depending from the tubing hanger the other facing upwardly on an orientation sleeve carried by the spool tree.

Whereas modern well technology provides continuous access to the tubing annulus around the tubing string, it has generally been accepted as being difficult, if not impossible, to provide continuous venting and/or monitoring of the pressure in the production casing annulus, that is the annulus around the innermost casing string. This has been because the production casing annulus must be securely sealed whist the Christmas tree is fitted in place of the drilling BOP, and the Christmas tree has only been fitted after the tubing string and hanger has been run in, necessarily inside the production casing hanger, so that the production casing hanger is no longer accessible for the opening of a passageway from the production casing annulus. However, the new arrangement, wherein the spool tree is fitted before the tubing string is run in provides adequate protected access through the BOP and spool tree to the production casing hanger for controlling a passage from the production casing annulus.

For this purpose, the wellhead may include a production casing hanger landed in the wellhead housing below the spool tree; an isolation sleeve which is sealed at its lower end to the production casing hanger and at its upper end to the spool tree to define an annular void between the isolation sleeve and the housings and an adapter located in the annular space and providing part of a passage from the production casing annulus to a production casing annulus pressure monitoring port in the spool tree, the adapter having a valve for opening and closing the passage, and the valve being operable through the spool tree after withdrawal of the isolation sleeve up through the spool tree. The valve may be provided by a gland nut, which can be screwed up and down within a body of the adapter to bring parts of the passage formed in the gland nut and adapter body, respectively, into and out of alignment with one another. The orientation sleeve for the tubing hanger maybe provided within the isolation sleeve.

Production casing annulus pressure monitoring can then be set up by method of completing a cased well in which a production casing hanger is fixed and sealed by a seal assembly to a wellhead housing, the method comprising, with BOP installed on the housing, removing the seal assembly and replacing it with an adapter which is manipulatable between configurations in which a passages from the production casing annulus up past the production casing hanger is open or closed; with the passage closed, removing the BOP and fitting to the housing above the production casing hanger a spool tree having an internal landing for a tubing hanger; installing a BOP on the spool trees running a tool down through the BOP and spool tree to manipulate the valve and open the passage; inserting through the BOP and spool tree an isolation sleeve, which seals to both the production casing and spool tree and hence defines between the sleeve and casing an annular void through which the passage leads to a production casing annulus pressure monitoring port in the spool tree; and running a tubing string down through the BOP and spool tree until the tubing hanger lands in the spool tree with lateral outlet ports in the tubing hanger and spool tree for production fluid flow, in alignment with one another.

According to a further feature of the invention the spool tree has a downwardly depending location manurel which is a close sliding fit within a bore of the wellhead housing. The close fit between the location mandrel of the spool tree and the wellhead housing provides a secure mounting which transmits inevitable bending stresses to the housing from the heavy equipment, such as a BOP, which projects upwardly from the top of the wellhead housing, without the need for excessively sturdy connections. The location mandrel may be formed as an integral part of the body of the spool tree, or maybe a separate part which is securely fixed, oriented and sealed to the body.

Pressure integrity between the wellhead housing and spool tree may be provided by two seals positioned in series one forming an environmental seal (such as an AX gasket) between the spool tree and the wellhead housing, and the other forming a production seal between the location mandrel and either the wellhead housing or the production casing hanger.

During workover operations, the production casing annulus can be resealed by reversing the above steps, if necessary after setting plugs or packers down hole.

When production casing pressure monitoring is unnecessary, so that no isolation sleeve is required, the orientation sleeve carried by the spool tree for guiding and rotating the tubing hanger down into the correct angular orientation maybe part of the spool tree location mandrel itself.

Double barrier isolation, that is to say two barriers in series, are generally necessary for containing pressure in a well. If a spool tree is used instead of a conventional Christmas tree, there are no valves within the vertical production and annulus fluid flow bores within the tree, and alternative provision must be made for sealing the bore or bores through the top of the spool tree which provide for wire line or drill pipe access.

In accordance with a further feature of the invention, at least one vertical production fluid bore in the tubing hanger is sealed above the respective lateral production fluid outlet port by means of a removable plug, and the bore through the spool tree being sealed above the tubing hanger by means of a second removable plug.

With this arrangement, the first plug, takes the function of a conventional swab valve, and may be a wireline set plug. The second plug could be a stopper set in the spool tree above the tubing hanger by, e.g., a drill pipe running tool. The stopper could contain at least one wireline retrievable plug which would allow well access when only wire line operations are called for. The second plug should seal and be locked internally into the spool tree as it performs a barrier to the well when a BOP or intervention module is deployed. A particular advantage of this double plug arrangement is that, as is necessary to satisfy authorities in some jurisdictions, the two independent barriers are provided in mechanically separate parts, namely the tubing hanger and its plug and the second plug in the spool tree.

A further advantage arises if a workover port extends laterally through the wall of the spool tree from between the two plugs; a tubing annulus fluid port extends laterally through the wall of the spool tree from the tubing annulus; and these two ports through the spool tree are interconnected via an external flow line containing at least one actuated valve. The bore from the tubing annulus can then terminate at the port in the spool tree and no wireline access to the tubing annulus bore is necessary through the spool tree as the tubing annulus bore can be connected via the interplug void to choke or kill lines, i.e. a BOP annulus, so that downhole circulation is still available. It is then only necessary to provide wireline access at workover situations to the production bore or bores. This considerably simplifies workover BOP and/or riser construction. When used in conjunction with the plug at the top of the spool tree, the desirable double barrier isolation is provided by the spool tree plug over the tubing hanger, or workover valve from the production flow.

When the well is completed as a multi production bore well, in which the tubing hanger has at least two vertical production through bores each with a lateral production fluid flow port aligned with the corresponding port in the spool tree, at least two respective connectors may be provided for selective connection of a single bore wire line running tool to one or other of the production bores, each connector having a key for entering a complementary formation at the top of the spool tree to locate the connector in a predetermined angular orientation relatively to the spool tree. The same type of alternative connectors may be used for providing wireline or other running tool access to a selected one of a plurality of functional connections, e.g. electrical or hydraulic couplings, at the upper end of the tubing hanger.

BRIEF DESCRIPTION OF THE DRAWINGS

The development and completion of a subsea wellhead in accordance with the present invention are illustrated in the accompanying drawings, in which:

FIGS. 1 to 8 are vertical axial sections showing successive steps in development and completion of the wellhead, the Figure numbers bearing the letter A being enlargements of part of the corresponding Figures of same number without the A:

FIG. 9 is a circuit diagram showing external connections to the spool 3;

FIG. 10 is a vertical axial section through a completed dual production bore well in production mode;

FIGS. 11 and 12 are vertical axial sections showing alternative connectors to the upper end of the dual production bore wellhead during work over; and,

FIGS. 13, 13A and 13B show the seating of one of the connectors in the spool tree.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 shows the upper end of a cased well having a wellhead housing 20, in which casing hangers, including an uppermost production casing hanger 21 for, for example, 9 ⅝" or 10¾" production casing is mounted in conventional manner. FIG. 1 shows a conventional drilling BOP 22 having rams 23 and kill and choke lines 24 connected to the upper end of the housing 20 by a drilling connector 25.

As seen in more detail in FIG. 1A, the usual mechanical seal assemblies between the production casing hanger 21 and the surrounding wellhead housing 20 have been removed and replaced through the BOP with an adapter 26 consisting of an outer annular body part 27 and an inner annular gland nut 28 which has a screw threaded connection to the body 27 so that it can be screwed between a lowered position shown on the right hand side of FIG. 1A, in which radial ducts 29 and 30, respectively in the body 27 and nut 28, are in communication with one another, and a raised position shown on the left hand side of FIG. 1A, in which the ducts are out of communication with one another. The duct 29 communicates through a conduit 31 between a depending portion of the body 27 and the housing 20, and through a conduit 32 passing through the production casing hanger 21, to the annulus surround the production casing. The duct 30 communicates through channels 33 formed in the radially inner surface of the nut 28, and hence to a void to be described. The cooperation between the gland nut 28 and body 27 of the adapter therefore acts as a valve which can open and close a passage up past the production casing hanger from the production casing annulus. After appropriate testing, a tool is run in through the BOP and, by means by radially projecting spring lugs engaging in the channels 33, rotates the gland nut 28 to the valve closed position shown on the right hand side on FIG. 1A. The well is thus resealed and the drilling BOP 22 can temporarily be removed.

As shown in FIGS. 2 and 2A, the body of a tree spool 34 is then lowered on a tree installation tool 35, using conventional guide post location, or a guide funnel in case of deep water, until a spool tree mandrel 36 is guided into alignment with and slides as a close machined fit, into the upper end of the wellhead housing 20, to which the spool tree is then fixed via a production connector 37 and bolts 38. The mandrel 36 is actually a separate part which is bolted and sealed to the rest of the spool tree body. As seen particularly in FIG. 2A a weight set AX gasket 39, forming a metal to metal environmental seal is provided between the spool tree body and the wellhead housing 20. In addition two sets of sealing rings 40 provide, in series with the environmental seal, a production fluid seal externally between the ends to the spool tree mandrel 36 to the spool tree body and to the wellhead housing 20. The intervening cavity can be tested through a test part 40A. The provision of the adapter 26 is actually optional, and in its absence the lower end of the spool tree mandrel 36 may form a production seal directly with the production casing hanger 21. As is also apparent from reasons which will subsequently become apparent, the upper radially inner edge of the spool tree mandrel projects radially inwardly from the inner surface of the spool tree body above, to form a landing shoulder 42 and at least one machined key slot 43 is formed down through the landing shoulder.

As shown in FIG. 3, the drilling BOP 22 is reinstalled on the spool tree 34. The tool 44 used to set the adapter in FIG. 1, having the spring dogs 45, is again run in until it lands on

the shoulder 42, and the spring dogs 45 engage in the channels 33. The tool is then turned to screw the gland nut 28 down within the body 27 of the adapter 26 to the valve open position shown on the right hand side in FIG. 1A. It is now safe to open the production casing annulus as the well is protected by the BOP.

The next stage, shown in FIGS. 4 and 4A, is to run in through the BOP and spool tree on an appropriate tool 44A a combined isolation and orientation sleeve 45. This lands on the shoulder 42 at the top of the spool tree mandrel and is rotated until a key on the sleeve drops into the mandrel key slot 43. This ensures precise angular orientation between the sleeve 45 and the spool tree 34, which is necessary, and in contrast to the angular orientation between the spool tree 34 and the wellhead casing, which is arbitrary. The sleeve 45 consists of an external cylindrical portion, an upper external surface of which is sealed by ring seals 46 to the spool tree 34, and the lower external surface of which is sealed by an annular seal 47 to the production casing hanger 21. There is thus provided between the sleeve 45 and the surrounding wellhead casing 20 a void 48 with which the channels 33, now defined radially inwardly by the sleeve 45, communicate. The void 48 in turn communicates via a duct 49 through the mandrel and body of the spool tree 34 to a lateral port. It is thus possible to monitor and vent the pressure in the production casing annulus through the passage provided past the production casing hanger via the conduits 32, 31 the ducts 29 and 30, the channels 33, shown in FIG. 1A, the void 48, the duct 49, and the lateral port in the spool tree. In the drawings, the radial portion of the duct 49 is shown apparently communicating with a tubing annulus, but this is draughtsman's licence and the ports from the two annuli are, in fact, angularly and radially spaced.

Within the cylindrical portion of the sleeve 45 is a lining, which may be fixed in the cylindrical portion, or left after internal machining of the sleeve. This lining provides an orientation sleeve having an upper/edge forming a cam 50. The lowermost portion of the cam leads into a key slot 51.

As shown in FIGS. 5, 6 and 6A a tubing string of production tubing 53 on a tubing hanger 54 is run in through the BOP 22 and spool tree 34 on a tool 55 until the tubing hanger lands by means of a keyed shoulder 56 on a landing in the spool tree and is locked down by a conventional mechanism 57. The tubing hanger 54 has a depending orientation sleeve 58 having an oblique lower edge forming a cam 59 which is complementary to the cam 50 in the sleeve 45 and, at the lower end of the cam, a downwardly projecting key 60 which is complementary to the key slot 51. The effect of the cams 50 and 59 is that, irrespective of the angular orientation of the tubing string as it is run in, the cams will cause the tubing hanger 54 to be rotated to its correct angular orientation relatively to the spool tree and the engagement of the key 60 in the key slot 51 will lock this relative orientation between the tubing hanger and spool tree, so that lateral production and tubing annulus fluid flow ports 61 and 62 in the tubing hanger 54 are in alignment with respective lateral production and tubing annulus fluid flow ports 63 and 64 through the wall of the spool tree. Metal to metal annulus seals 65, which are set by the weight of the tubing string, provide production fluid seals between the tubing hanger 54 and the spool tree 34. Provision is made in the top of the tubing hanger 54 for a wireline set plug 66. The keyed shoulder 56 of the tubing hanger lands in a complementary machined step in the spool tree 34 to ensure ultimate machined accuracy of orientation between the tubing hanger 54 and the spool tree 34.

FIG. 7 shows the final step in the completion of the spool tree. This involves the running down on drill pipe 67 through

the BOP, an internal isolation stopper 68 which seals within the top of the spool tree 34 and has an opening closed by an in situ wireline activated plug 69. The BOP can then be removed leaving the wellhead in production mode with double barrier isolation at the upper end of the spool tree provided by the plugs 66 and 69 and the stopper 68. The production fluid outlet is controlled by a master control valve 70 and pressure through the tubing annulus outlet ports 62 and 64 is controlled by an annulus master valve 71. The other side of this valve is connected, through a workover valve 72 to a lateral workover port 73 which extends through the wall of the spool tree to the void between the plugs 69 and 66. With this arrangement, wireline access to the tubing annulus in and downstream of a tubing hanger is unnecessary as any circulation of fluids can take place through the valves 71 and 72, the ports 62, 64 and 73, and the kill or choke lines of any BOP which has been installed. The spool tree in the completed production mode is shown in FIG. 8.

FIG. 9 shows valve circuitry associated with the completion and, in addition to the earlier views, shows a production fluid isolation valve 74, a tubing annulus valve 75 and a cross over valve 76. With this arrangement a wide variety of circulation can be achieved down hole using the production bore and tubing annulus, in conjunction with choke and kill lines extending from the BOP and through the usual riser string. All the valves are fail/safe closed if not actuated.

The arrangement shown in FIGS. 1 to 9 is a mono production bore wellhead which can be accessed by a single wireline or drill pipe, and the external loop from the tubing annulus port to the void between the two plugs at the top of the spool tree avoids the need for wireline access to the tubing annulus bore.

FIG. 10 corresponds to FIG. 8 but shows a 5½ inch ×2⅞ inch dual production bore wellhead with primary and secondary production tubing 53A and 53B. Development and completion are carried out as with the monobore wellhead except that the spool tree 34A and tubing hanger 54A are elongated to accommodate lateral outlet ports 61A, 63A for the primary production fluid flow from a primary bore 80 in the tubing hanger to a primary production master valve 70A, and lateral outlet ports 62A,64A for the secondary production fluid flow from a secondary bore 81 in the tubing hanger to a secondary production master valve 70B. The upper ends of the bores 80 and 81 are closed by wireline plugs 66A and 66B. A stopper 68A, which closes the upper end of the spool tree 34A has openings, in alignment with the plugs 66A and 66B, closed by wireline plugs 69A and 69B.

FIGS. 11 and 12 show how a wireline 77 can be applied through a single drill pipe to activate selectively one or other of the two wireline plugs 66A and 66B in the production bores SO and 81 respectively. This involves the use of a selected one of two connectors 82 and 83. In practice, a drilling BOP 22 is installed and the stopper 68A is removed. Thereafter the connector 82 or 83 is run in on the drill pipe or tubing until it lands in, and is secured and sealed to the spool tree 34A. FIGS. 13, 13A and 13B show how the correct angular orientation between the connector 82 or 83 and the spool tree 34A, is achieved by wing keys 84, which are guided by Y-shaped slots 85 in the upper inner edge of the spool tree, first to bring the connectors into the right angular orientation, and then to allow the relative axial movement between the parts to enable the stabbing function when the wireline connector engages with its respective pockets above plug 66A or 66B. To ensure equal landing forces and concentricity on initial contact, two keys 84A and 84B are recommended. As the running tool is slowly rotated under a new control weight, it is essential that the tool only enters in one fixed orientation. To ensure this key 84A is wider than key 84B and its respective Y-shaped slots. It will be seen that one of the connectors 82 has a guide duct 86 which leads the wireline to the plug 66B whereas the other connector 83 has a similar guide duct 87 which leads the wireline to the other plug 66A.

We claim:

1. A method of completing a cased well in which a production casing hanger is fixed and sealed by a seal assembly to a wellhead housing, the method comprising, with a BOP installed on the housing, removing the seal assembly and replacing it with an adapter which is manipulatable between configurations in which a passage from a production casing annulus up past the production casing hanger is open or closed; with the passage closed, removing the BOP and fitting to the housing above the production casing hanger a spool tree having an internal landing for a tubing hanger (54); installing the BOP on the spool tree; running a tool down through the BOP and spool tree to manipulate the valve and open the passage; inserting through the BOP and spool tree an isolation sleeve, which seals to both the production casing and spool tree and hence defines between the sleeve and casing an annular void through which the passage leads to a production casing annulus pressure monitoring port in the spool tree; and running a tubing string down through the BOP and spool tree until the tubing hanger lands in the spool tree with lateral outlet ports in the tubing hanger and spool tree for production fluid flow, in alignment with one another.

2. A wellhead comprising:

a wellhead housing;

a spool tree fixed and sealed to the housing, and having at least a lateral production fluid outlet port connected to a valve;

a tubing hanger landed within the spool tree at a predetermined angular position at which a lateral production fluid outlet port in the tubing hanger is in alignment with that in the spool tree; 'the tubing hanger and spool tree having complementary guide means to rotate the tubing hanger into the predetermined angular position relatively to the spool tree as the tubing hanger is lowered on to its landing, the guide means being provided by complementary oblique edge surfaces, one facing downwards on an orientation sleeve depending from the tubing hanger and the other facing upwards on an orientation sleeve carried by the spool tree;

a production casing hanger carried in the housing below the spool tree;

an isolation sleeve which is sealed at its lower end to the production casing hanger and at its upper end to the spool tree to define an annular void between the isolation sleeve and the housing; and

an adapter located in the annular void and providing part of a passage from a production casing annulus to a production casing annulus pressure monitoring port in the spool tree, the adapter having a valve for opening and closing the passage, the valve being operable through the spool tree after withdrawal of the isolation sleeve up through the spool tree.

3. A wellhead according to claim 2, in which the valve is provided by a gland nut, which can be screwed up and down within a body of the adapter to bring parts of the passage formed in the gland nut and adapter body, respectively, into and out of alignment with one another.

4. A wellhead according to claim 3, which includes a production casing hanger carried in the housing below the

spool tree; an isolation sleeve which is sealed at its lower end to the production casing hanger and at its upper end to the spool tree to define an annular void between the isolation sleeve and the housing; and an adapter located in the annular void and providing part of a passage from the production casing annulus to a production casing annulus pressure monitoring port in the spool tree, the adapter having a valve for opening and closing the passage, and the valve being operable through the spool tree after withdrawal of the isolation sleeve up through the spool tree, wherein the orientation sleeve is provided within the isolation sleeve.

5. A wellhead according to claim 2 wherein the spool tree has a downwardly depending mandrel which is a close sliding fit within a bore of the housing.

6. A wellhead according to claim **5**, in which an environmental seal is provided between the spool tree and the housing, and a production seal is provided in series with the environmental seal between a location mandrel and either the wellhead housing or a production casing hanger.

7. A wellhead according to claim 2 wherein at least one vertical production fluid bore in the tubing hanger is sealed above the respective lateral production fluid outlet port by means of a first removable plug, and the bore through the spool tree being sealed above the tubing hanger by means of a second removable plug.

8. A wellhead according to claim 7 wherein the first plug is a wireline plug and the second plug is a stopper which contains at least one opening closed by a wireline plug.

9. A wellhead according to claim 2 wherein the tubing hanger has a shoulder with an orientation key which cooperates with a landing in the spool tree to provide final direct relative angular orientation between the tubing hanger and spool tree.

10. A wellhead comprising:

a wellhead housing;

a spool tree fixed and sealed to the housing, and having at least a lateral production fluid outlet port connected to a valve;

a tubing hanger landed within the spool tree at a predetermined angular position at which a lateral production fluid outlet port in the tubing hanger is in alignment with that in the spool tree;

at least one vertical production fluid bore in the tubing hanger is sealed above the respective lateral production fluid outlet port by means of a first removable wireline plug, and the bore through the spool tree is sealed above the tubing hanger by means of a second removable stopper plug which contains at least one opening closed by a wireline plug;

a workover port extending laterally through the wall of the spool tree from between the two plugs; and

a tubing annulus fluid port extends laterally through the wall of the spool tree from a tubing annulus; the workover and tubing annulus ports through the spool tree are interconnected via an external loop line containing at least one valve.

11. A wellhead according to claim **10**, in which the tubing hanger has at least two separate functional connections at its upper end, separate connectors being provided for selective access of a single bore running tool to one of the functional connections, each connector having a key for entering a complementary formation at the top of the spool tree to locate the connector in a predetermined angular orientation relatively to the spool tree.

12. A multi production bore wellhead according to claim **11**, wherein the tubing hanger has at least two vertical production through bores each with a lateral production fluid flow port aligned with the corresponding port in the spool tree, at least two respective connectors being provided for selective connection of a single bore wire line running tool to one or other of the production bores, each connector having a key for entering a complementary formation at the top of the spool tree to locate the connector in a predetermined angular orientation relatively to the spool tree.

13. A wellhead comprising:

a wellhead housing;

a spool tree fixed and sealed to the housing;

a tubing hanger landed within the spool tree;

a production casing hanger carried in the housing below the spool tree to define the interior of a production casing annulus;

a fluid pressure passage operably connecting said production casing annulus to a production casing annulus pressure monitoring port in the spool tree; and

a valve for selective opening and closing of the passage, the valve comprising a gland nut which can be screwed up and down within the body of an adapter to bring parts of the passage formed in the gland nut and adapter body, respectively, into and out of alignment with each other.

* * * * *

EXHIBIT B

US006039119A

United States Patent [19]
Hopper et al.

[11] Patent Number: 6,039,119
[45] Date of Patent: *Mar. 21, 2000

[54] **COMPLETION SYSTEM**

[75] Inventors: **Hans Paul Hopper**, Hill House White Rashers; **Thomas G. Cassity**, Tyronos Sandy Lane Cobham, both of United Kingdom

[73] Assignee: **Cooper Cameron Corporation**, Houston, Tex.

[*] Notice: This patent is subject to a terminal disclaimer.

[21] Appl. No.: **08/679,560**

[22] Filed: **Jul. 12, 1996**

Related U.S. Application Data

[63] Continuation of application No. 08/204,397, filed as application No. PCT/US93/05246, May 28, 1993, Pat. No. 5,544, 707.

[30] **Foreign Application Priority Data**

Jun. 1, 1992 [EP] European Pat. Off. 92305014

[51] **Int. Cl.**[7] **E21B 33/03**

[52] **U.S. Cl.** **166/368**; 166/88.4; 166/95.1; 166/348; 166/382

[58] **Field of Search** 166/382, 368, 166/348, 339, 341, 347, 88, 89, 95, 208, 88.4, 95.1

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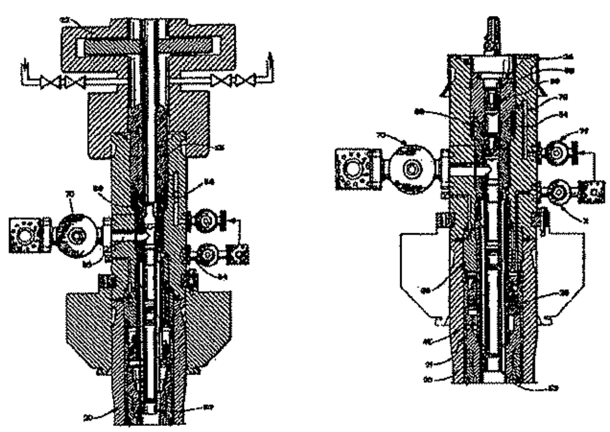
Primary Examiner—Hoang C. Dang
Attorney, Agent, or Firm—Conley, Rose & Tayon, P.C.

[57] **ABSTRACT**

A wellhead has, instead of a conventional Christmas tree, a spool tree (34) in which a tubing hanger (54) is landed at a predetermined angular orientation. As the tubing string can be pulled without disturbing the tree, many advantages follow, including access to the production casing hanger (21) for monitoring production casing annulus pressure, and the introduction of larger tools into the well hole without breaching the integrity of the well.

37 Claims, 16 Drawing Sheets



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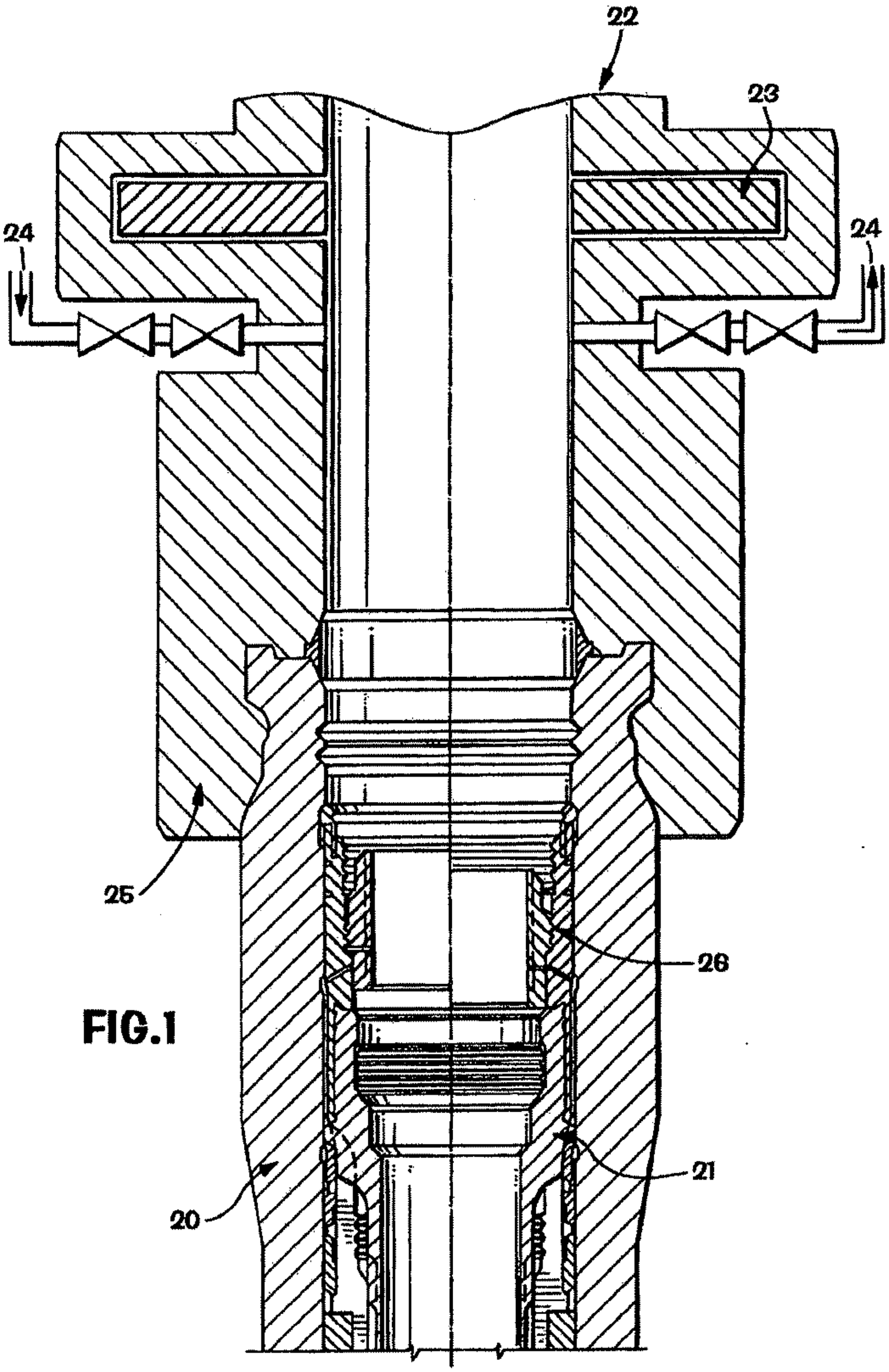


FIG.1

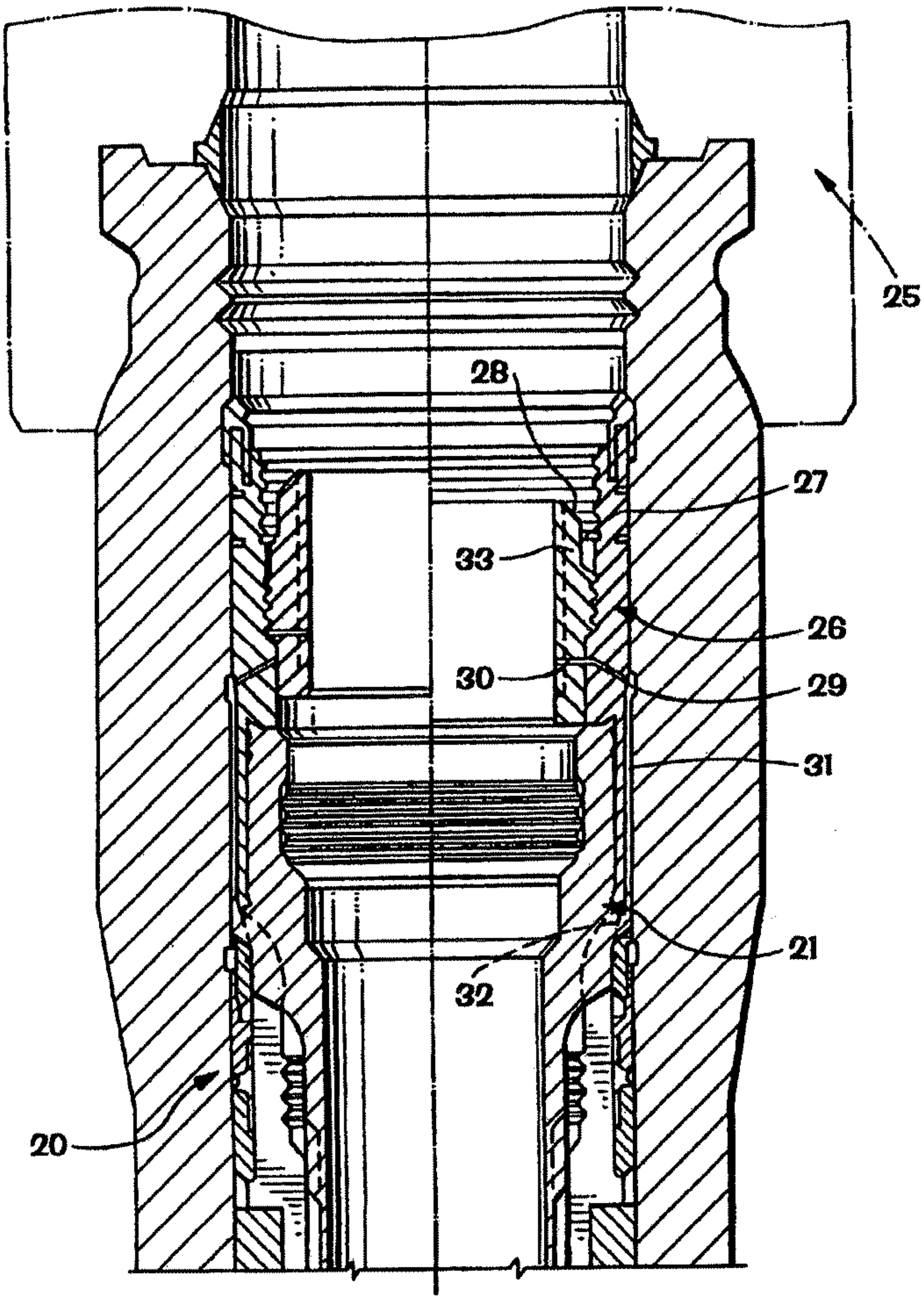
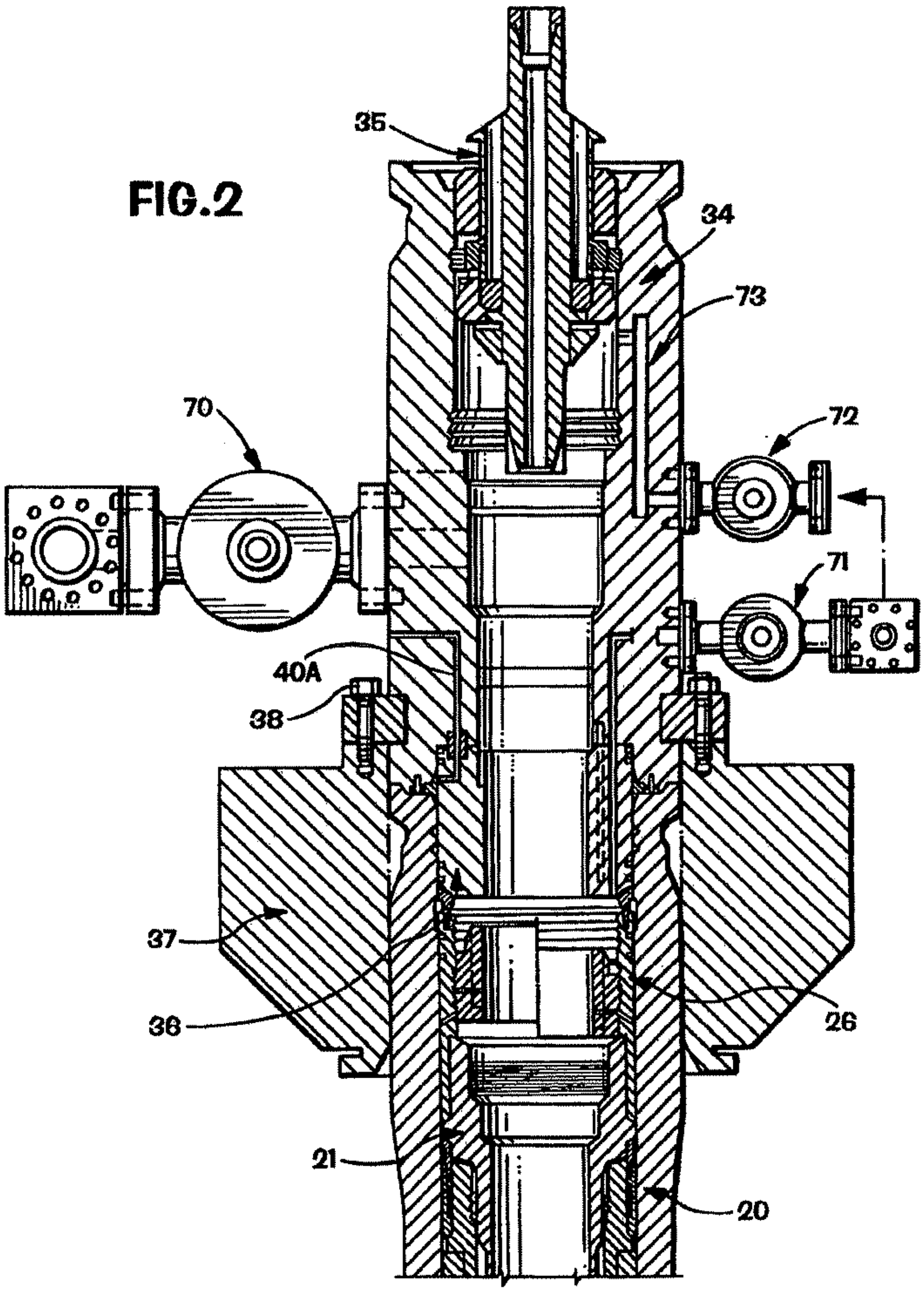


FIG.1A

FIG.2



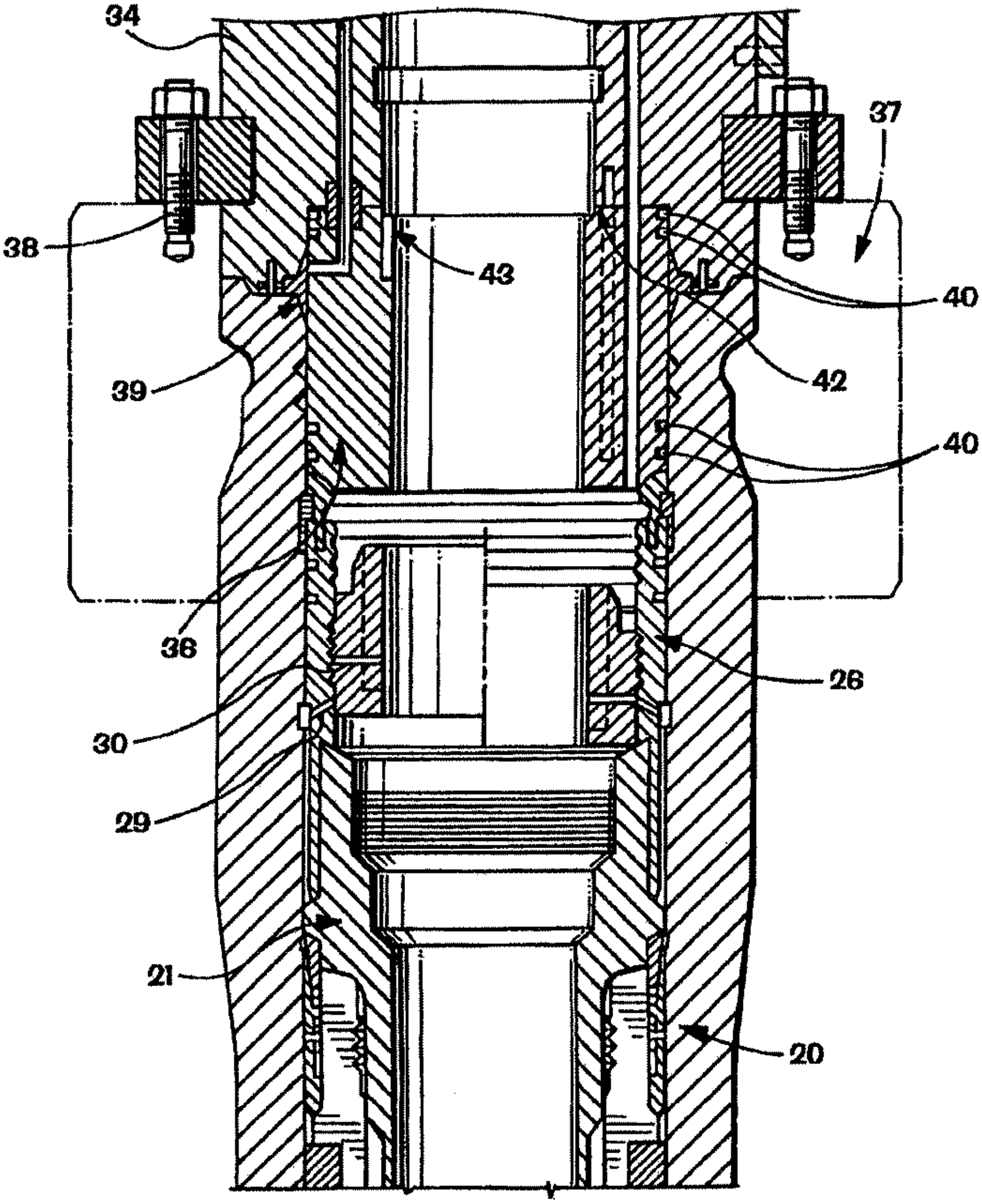


FIG.2A

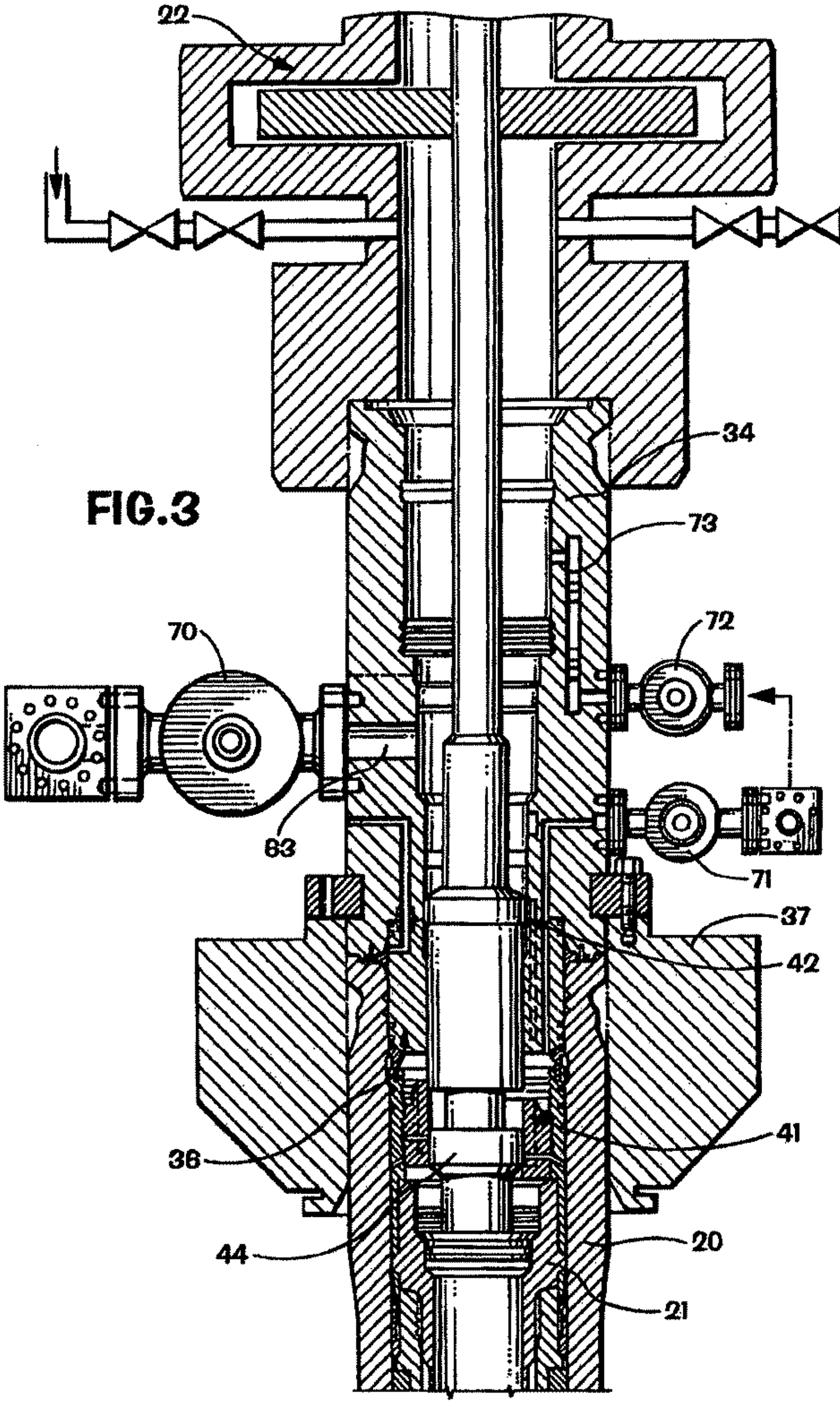
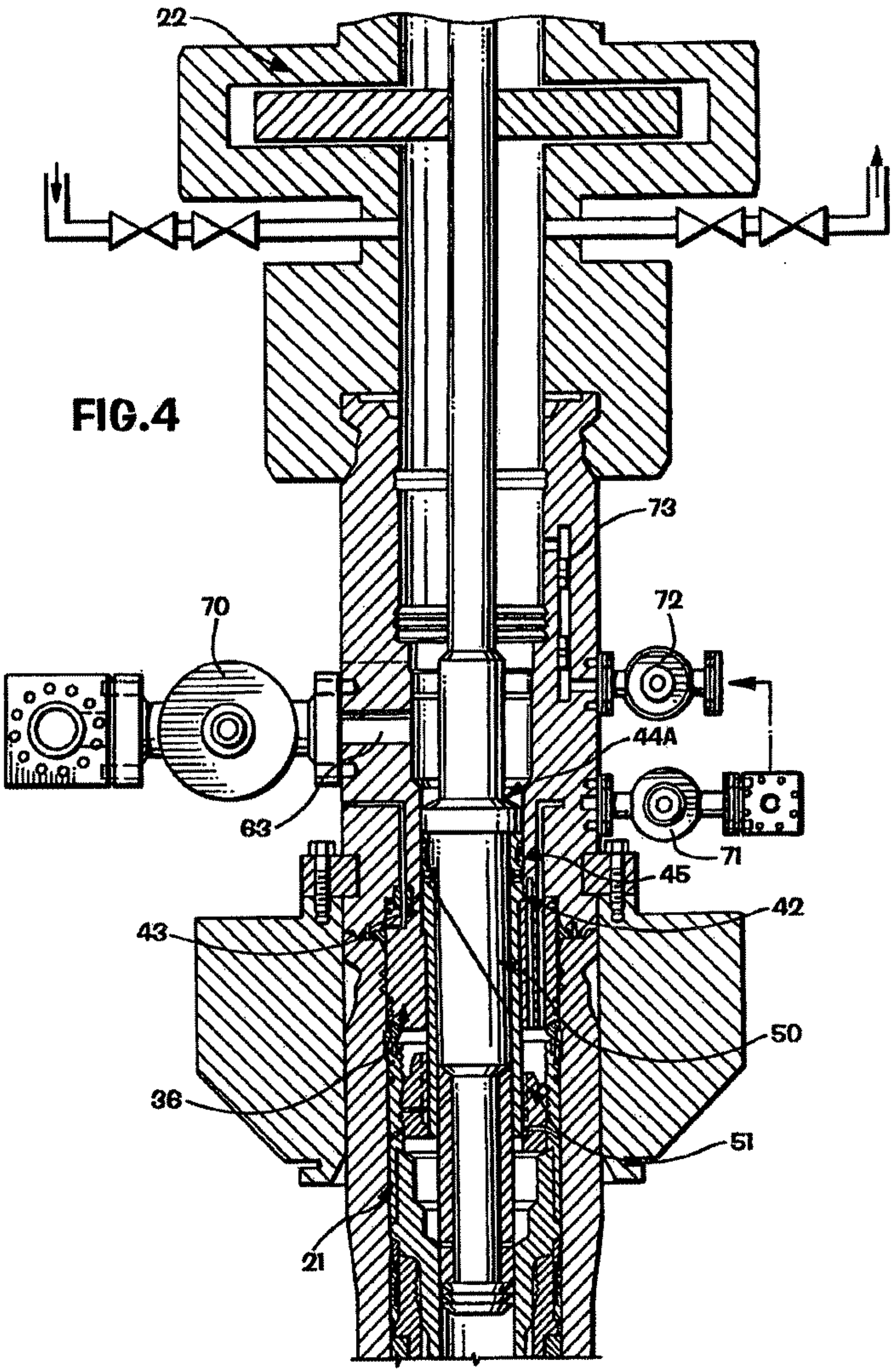


FIG.3

FIG.4



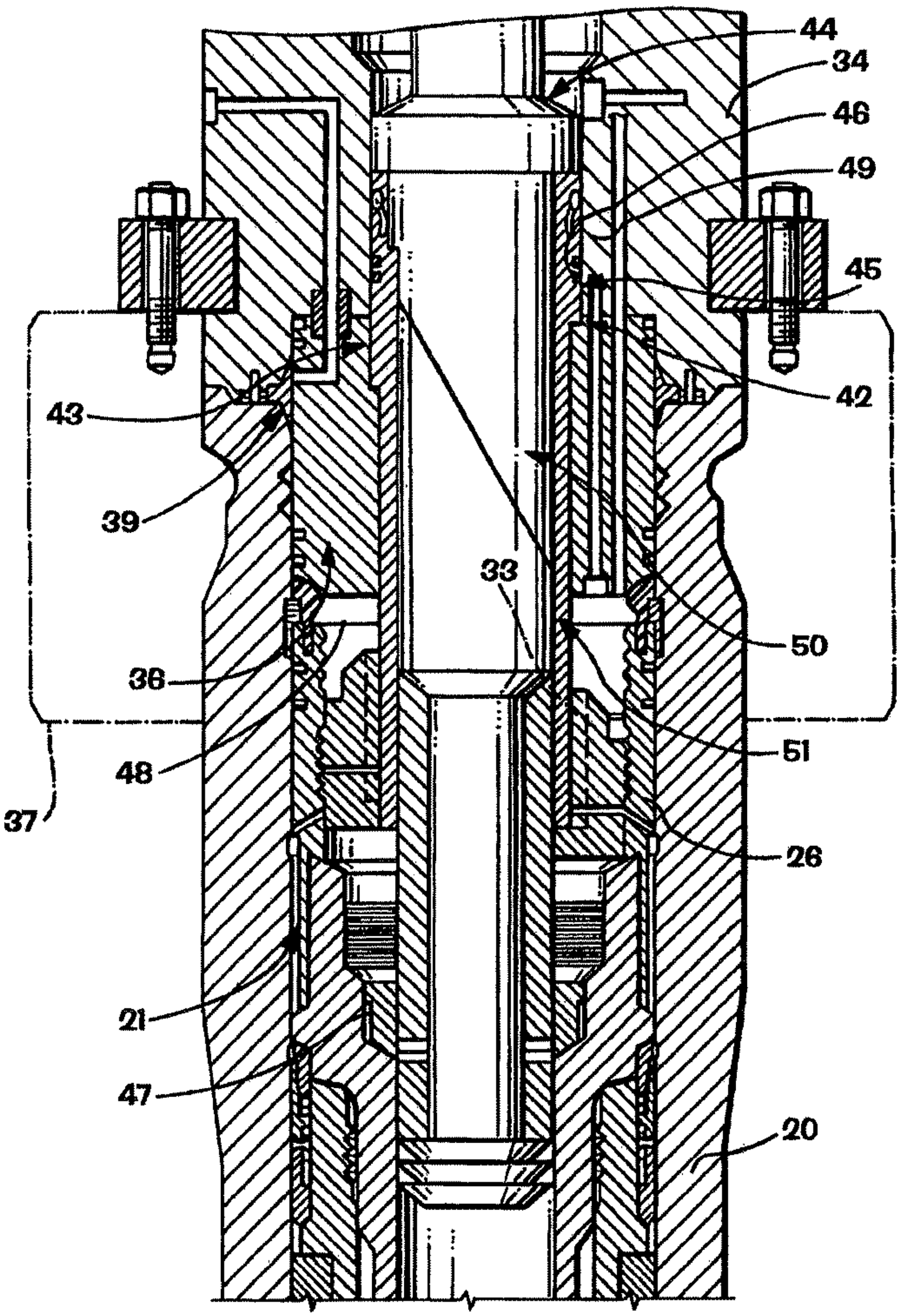


FIG.4A

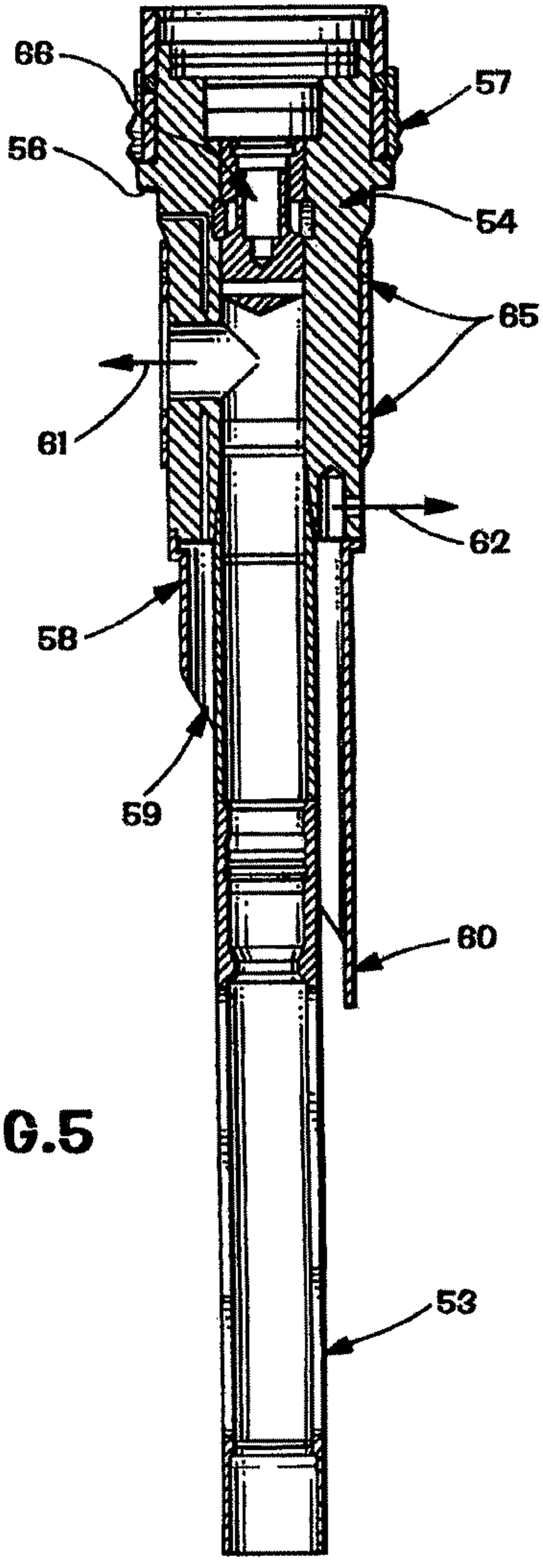


FIG.5

FIG.6

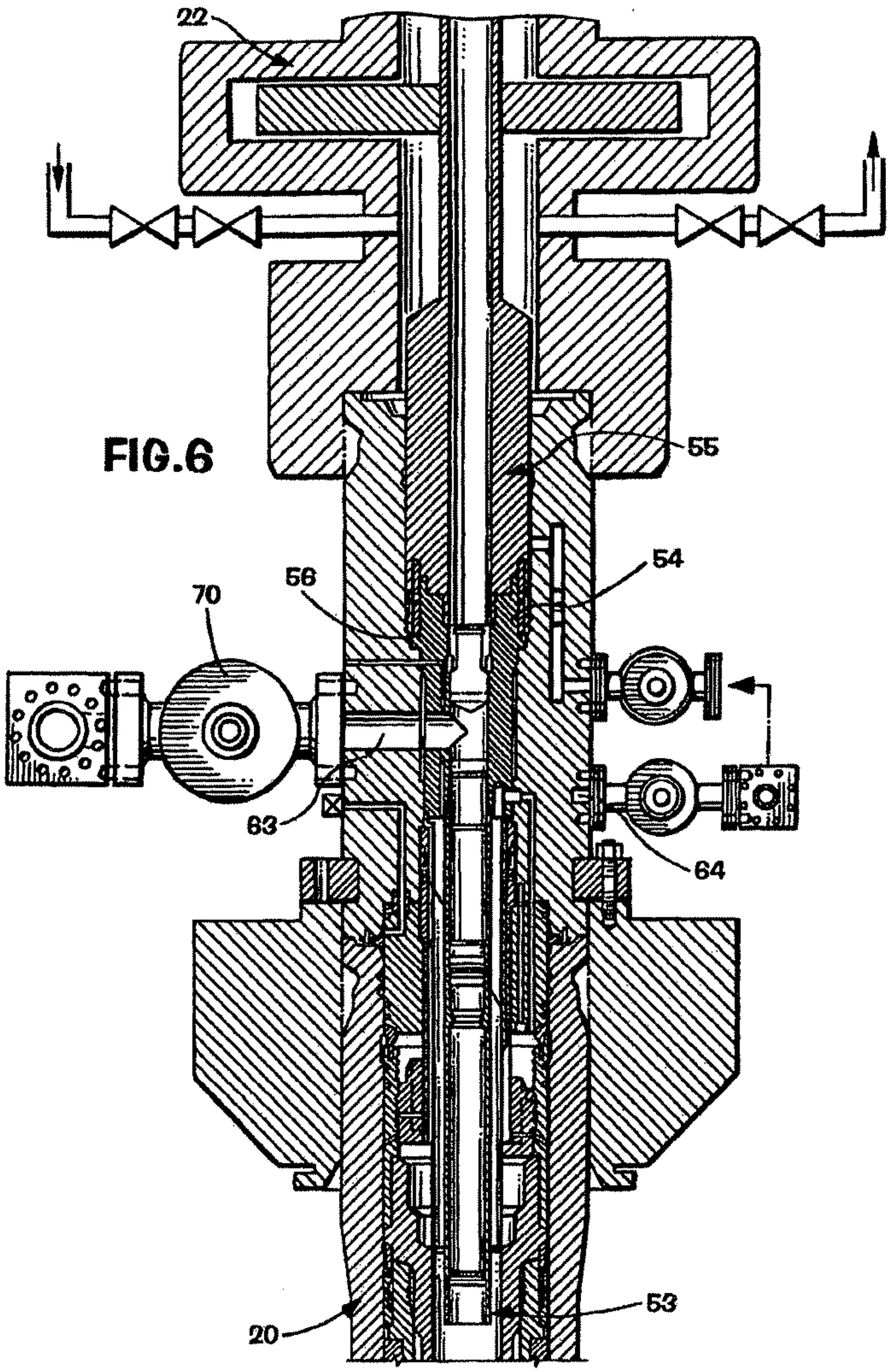
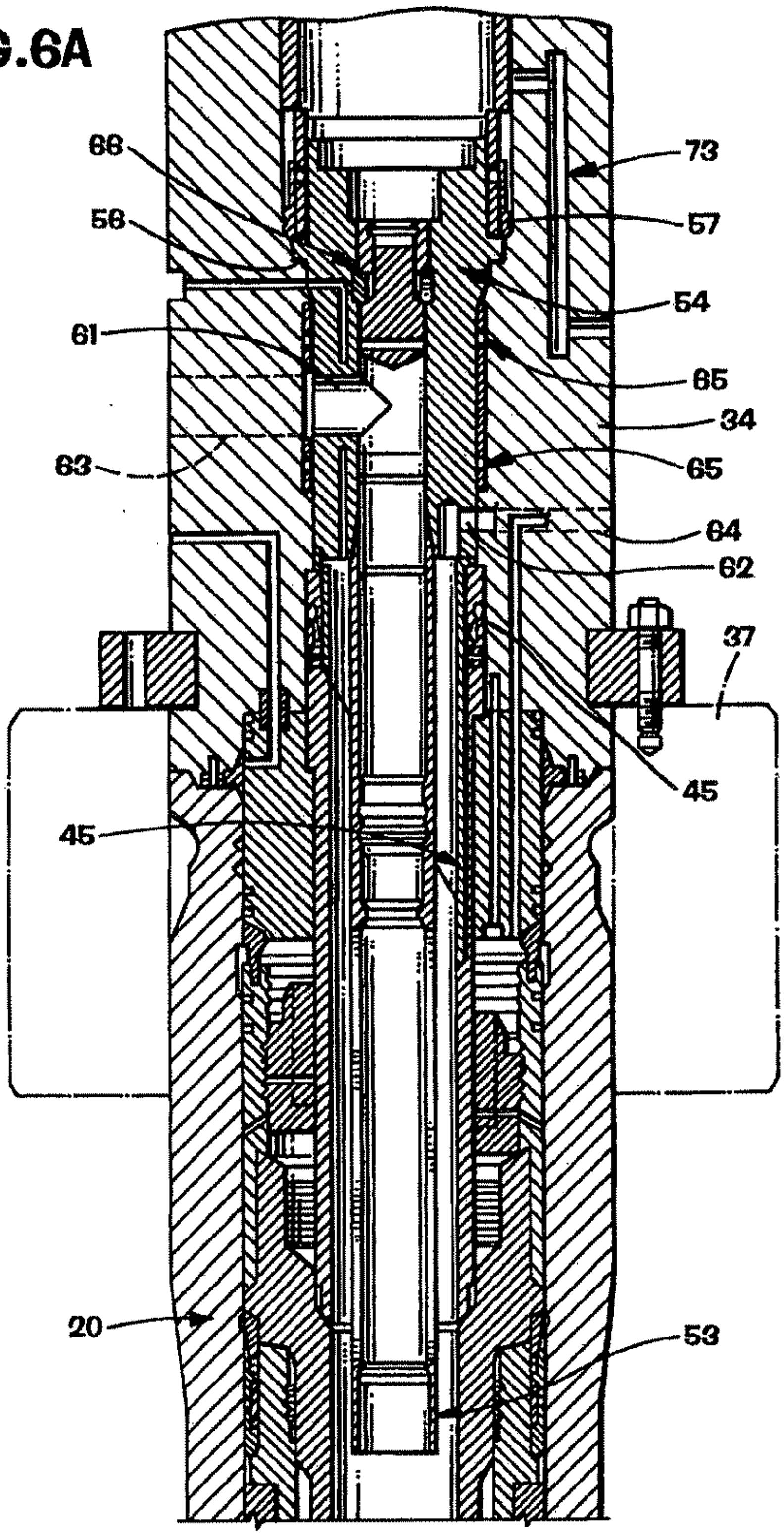


FIG.6A



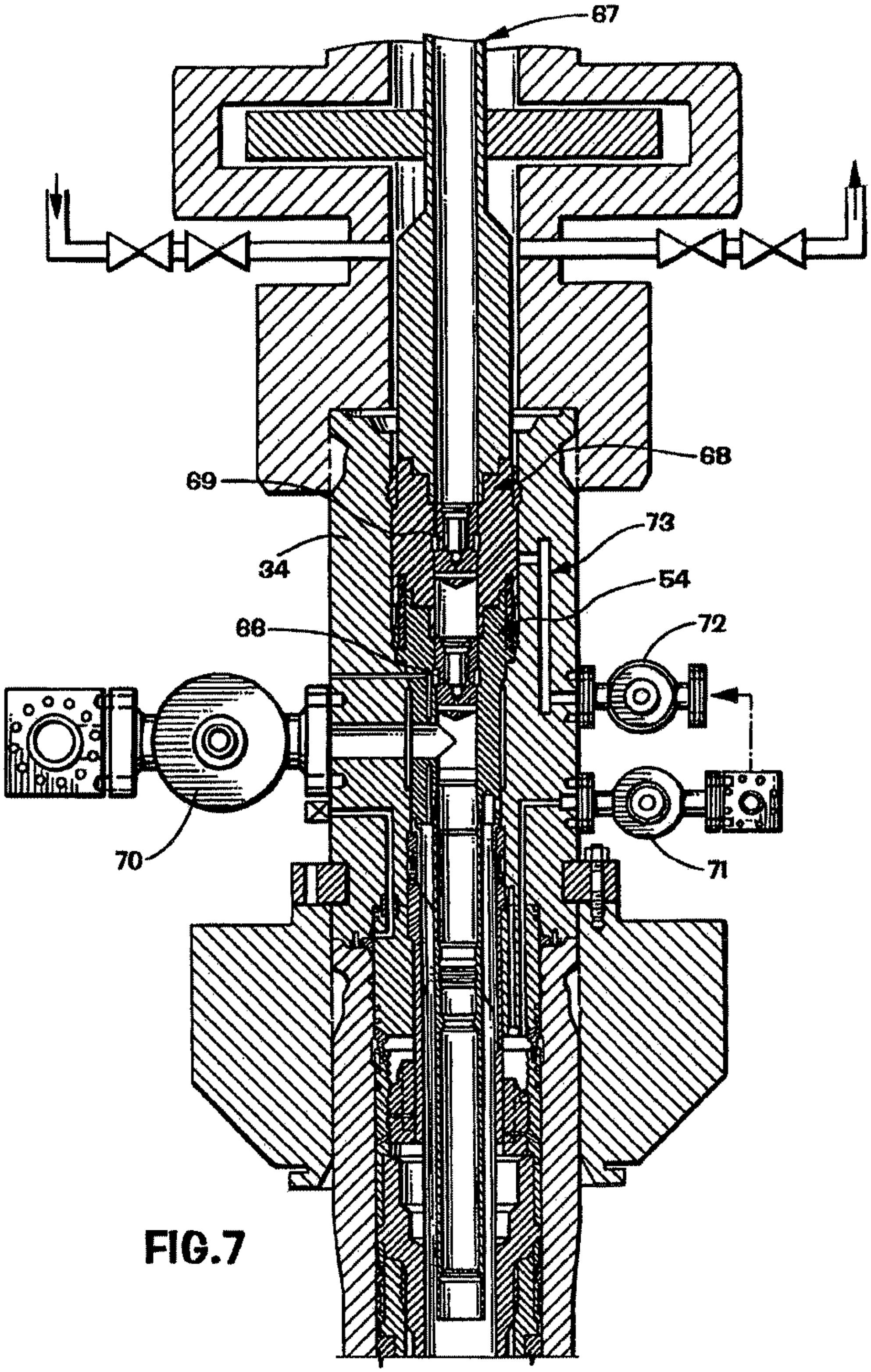


FIG.7

FIG.8

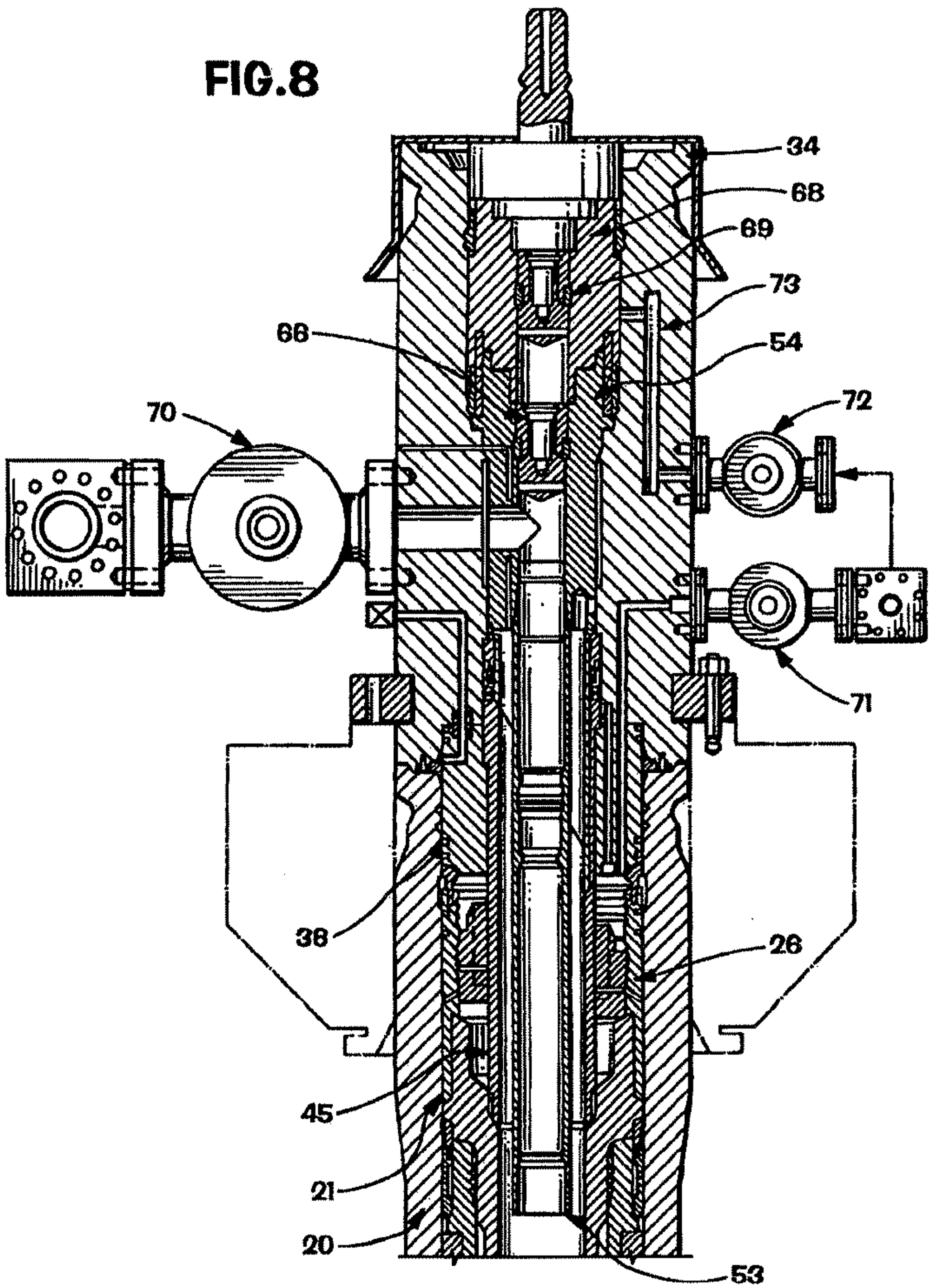


FIG.9

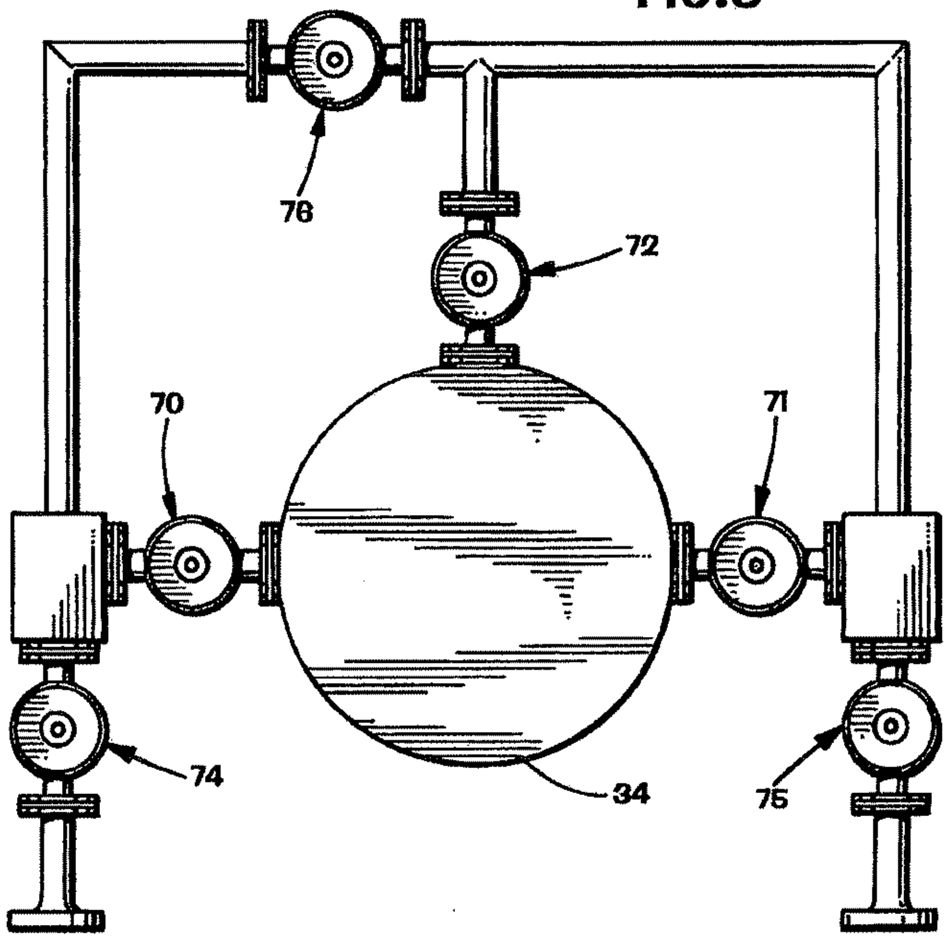


FIG.13

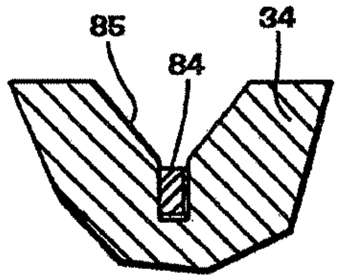


FIG.13A

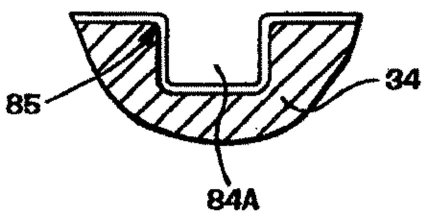


FIG.13B

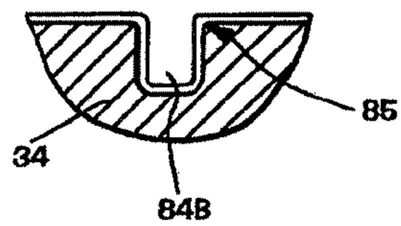
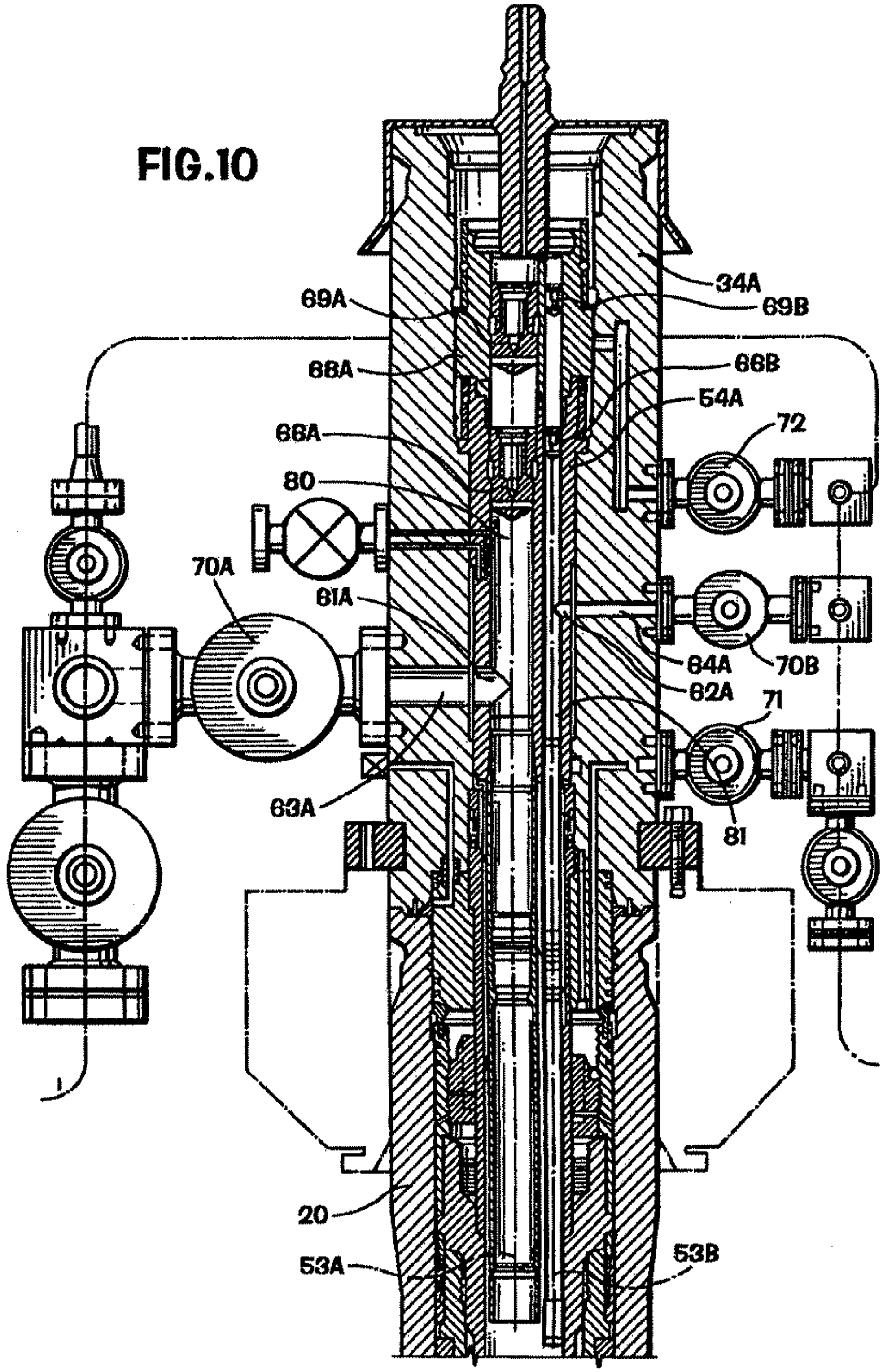


FIG.10



34A
69A
69B
68A
68B
54A
66A
72
80
70A
61A
64A
70B
62A
71
63A
81
20
53A
53B

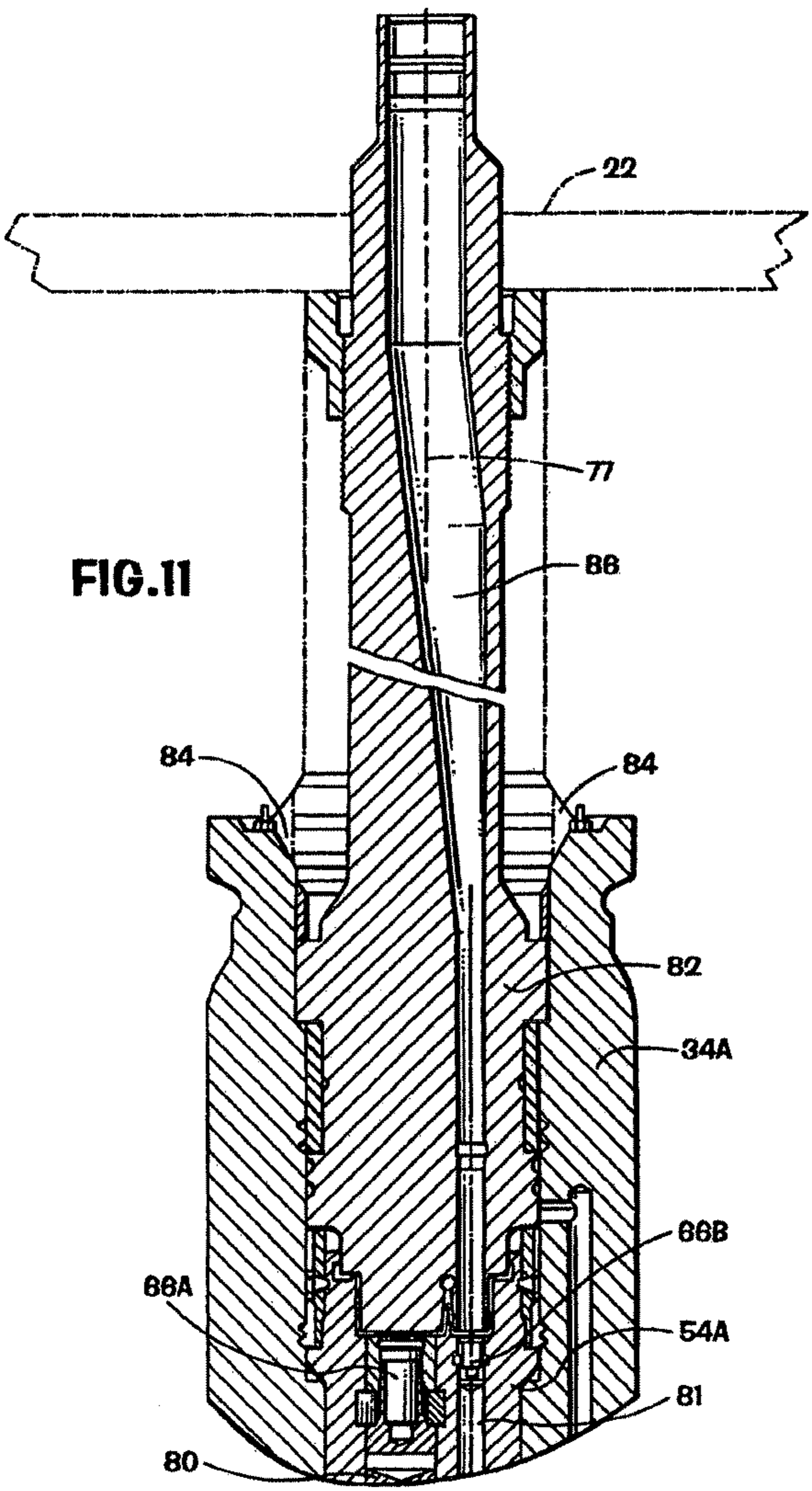
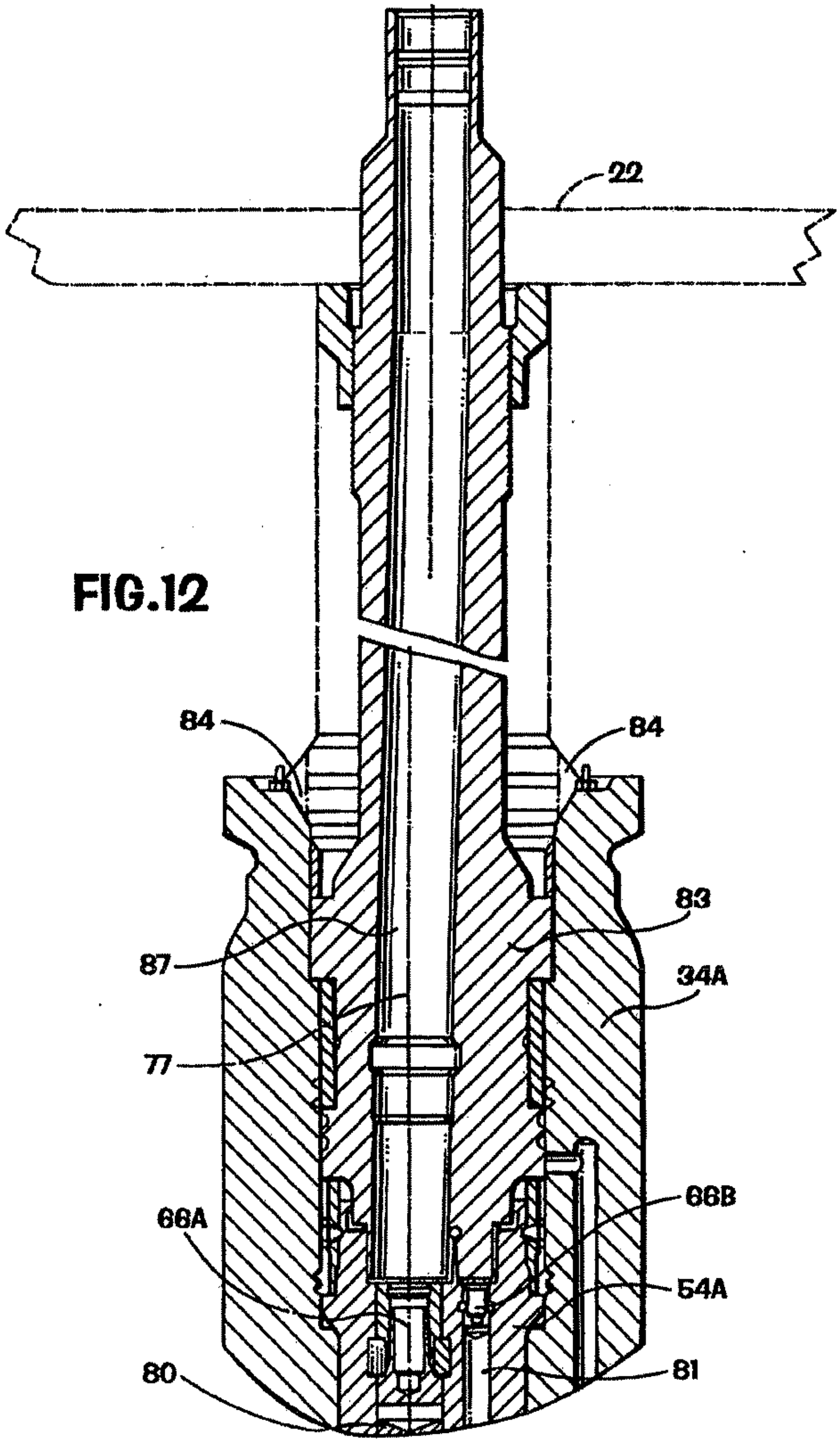


FIG.11

FIG.12



COMPLETION SYSTEM

This is a continuation of copending application Ser. No. 08/204,397 filed on Mar. 16, 1994 now U.S. Pat. No. 5,544,707, which claims the benefit of PCT application PCT/US93/05246 filed on May 28, 1993, which claims the priority of European Patent Office application 92305014 filed on Jun. 1, 1992.

Conventionally, wells in oil and gas fields are built up by establishing a wellhead housing, and with a drilling blow out preventer stack (BOP) installed, drilling down to produce the well hole whilst successively installing concentric casing strings, which are cemented at the lower ends and sealed with mechanical seal assemblies at their upper ends. In order to convert the cased well for production, a tubing string is run in through the BOP and a hanger at its upper end landed in the wellhead. Thereafter the drilling BOP stack is removed and replaced by a Christmas tree having one or more production bores containing actuated valves and extending vertically to respective lateral production fluid outlet ports in the wall of the Christmas tree.

This arrangement has involved problems which have, previously, been accepted as inevitable. Thus any operations down hole have been limited to tooling which can pass through the production bore, which is usually no more than five inch diameter, unless the Christmas tree is first removed and replaced by a BOP stack. However this involves setting plugs or valves, which may be unreliable by not having been used for a long time, down hole. The well is in a vulnerable condition whilst the Christmas tree and BOP stack are being exchanged and neither one is in position, which is a lengthy operation. Also, if it is necessary to pull the completion, consisting essentially of the tubing string on its hanger, the Christmas tree must first be removed and replaced by a BOP stack. This usually involves plugging and/or killing the well.

A further difficulty which exists, particularly with subsea wells, is in providing the proper angular alignment between the various functions, such as fluid flow bores, and electrical and hydraulic lines, when the wellhead equipment, including the tubing hanger, Christmas tree, BOP stack and emergency disconnect devices are stacked up. Exact alignment is necessary if clean connections are to be made without damage as the devices are lowered into engagement with one another. This problem is exacerbated in the case of subsea wells as the various devices which are to be stacked up are run down onto guide posts or a guide funnel projecting upwardly from a guide base. The post receptacles which ride down on to the guide posts or the entry guide into the funnel do so with appreciable clearance. This clearance inevitably introduces some uncertainty in alignment and the aggregate misalignment when multiple devices are stacked, can be unacceptably large. Also the exact orientation will depend upon the precise positions of the posts or keys on a particular guide base and the guides on a particular running tool or BOP stack and these will vary significantly from one to another. Consequently it is preferable to ensure that the same running tools or BOP stack are used for the same wellhead, or a new tool or stack may have to be specially modified for a particular wellhead. Further misalignments can arise from the manner in which the guide base is bolted to the conductor casing of the wellhead.

In accordance with the present invention, a wellhead comprises a wellhead housing; a spool tree fixed and sealed to the housing, and having at least a lateral production fluid outlet port connected to an actuated valve; and a tubing hanger landed within the spool tree at a predetermined angular position at which a lateral production fluid outlet port in the tubing hanger is in alignment with that in the spool tree.

With this arrangement, the spool tree, takes the place of a conventional Christmas tree but differs therefrom in having a comparatively large vertical through bore without any internal valves and at least large enough to accommodate the tubing completion. The advantages which are derived from the use of such spool tree are remarkable, in respect to safety and operational benefits.

Thus, in workover situations the completion, consisting essentially of the tubing string, can be pulled through a BOP stack, without disturbing the spool tree and hence the pressure integrity of the well, whereafter full production casing drift access is provided to the well through the large bore in the spool tree. The BOP can be any appropriate workover BOP or drilling BOP of opportunity and does not have to be one specially set up for that well.

Preferably, there are complementary guide means on the tubing hanger and spool tree to rotate the tubing hanger into the predetermined angular position relatively to the spool tree as the tubing hanger is lowered on to its landing. With this feature the spool tree can be landed at any angular orientation onto the wellhead housing and the guide means ensures that the tubing string will rotate directly to exactly the correct angular orientation relatively to the spool tree quite independently of any outside influence. The guide means to control rotation of the tubing hanger into the predetermined angular orientation relatively to the spool tree may be provided by complementary oblique edge surfaces one facing downwardly on an orientation sleeve depending from the tubing hanger the other facing upwardly on an orientation sleeve carried by the spool tree.

Whereas modern well technology provides continuous access to the tubing annulus around the tubing string, it has generally been accepted as being difficult, if not impossible, to provide continuous venting and/or monitoring of the pressure in the production casing annulus, that is the annulus around the innermost casing string. This has been because the production casing annulus must be securely sealed whist the Christmas tree is fitted in place of the drilling BOP, and the Christmas tree has only been fitted after the tubing string and hanger has been run in, necessarily inside the production casing hanger, so that the production casing hanger is no longer accessible for the opening of a passageway from the production casing annulus. However, the new arrangement, wherein the spool tree is fitted before the tubing string is run in provides adequate protected access through the BOP and spool tree to the production casing hanger for controlling a passage from the production casing annulus.

For this purpose, the wellhead may include a production casing hanger landed in the wellhead housing below the spool tree; an isolation sleeve which is sealed at its lower end to the production casing hanger and at its upper end to the spool tree to define an annular void between the isolation sleeve and the housing; and an adapter located in the annular space and providing part of a passage from the production casing annulus to a production casing annulus pressure monitoring port in the spool tree, the adapter having a valve for opening and closing the passage, and the valve being operable through the spool tree after withdrawal of the isolation sleeve up through the spool tree. The valve may be provided by a gland nut, which can be screwed up and down within a body of the adapter to bring parts of the passage formed in the gland nut and adapter body, respectively, into and out of alignment with one another. The orientation sleeve for the tubing hanger may be provided within the isolation sleeve.

Production casing annulus pressure monitoring can then be set up by method of completing a cased well in which a

production casing hanger is fixed and sealed by a seal assembly to a wellhead housing, the method comprising, with BOP installed on the housing, removing the seal assembly and replacing it with an adapter which is manipulatable between configurations in which a passages from the production casing annulus up past the production casing hanger is open or closed; with the passage closed, removing the BOP and fitting to the housing above the production casing hanger a spool tree having an internal landing for a tubing hanger; installing a BOP on the spool tree; running a tool down through the BOP and spool tree to manipulate the valve and open the passage; inserting through the BOP and spool tree an isolation sleeve, which seals to both the production casing and spool tree and hence defines between the sleeve and casing an annular void through which the passage leads to a production casing annulus pressure monitoring port in the spool tree; and running a tubing string down through the BOP and spool tree until the tubing hanger lands in the spool tree with lateral outlet ports in the tubing hanger and spool tree for production fluid flow, in alignment with one another.

According to a further feature of the invention the spool tree has a downwardly depending location mandrel which is a close sliding fit within a bore of the wellhead housing. The close fit between the location mandrel of the spool tree and the wellhead housing provides a secure mounting which transmits inevitable bending stresses to the housing from the heavy equipment, such as a BOP, which projects upwardly from the top of the wellhead housing, without the need for excessively sturdy connections. The location mandrel may be formed as an integral part of the body of the spool tree, or may be a separate part which is securely fixed, oriented and sealed to the body.

Pressure integrity between the wellhead housing and spool tree may be provided by two seals positioned in series one forming an environmental seal (such as an AX gasket) between the spool tree and the wellhead housing, and the other forming a production seal between the location mandrel and either the wellhead housing or the production casing hanger.

During workover operations, the production casing annulus can be resealed by reversing the above steps, if necessary after setting plugs or packers down hole.

When production casing pressure monitoring is unnecessary, so that no isolation sleeve is required, the orientation sleeve carried by the spool tree for guiding and rotating the tubing hanger down into the correct angular orientation may be part of the spool tree location mandrel itself.

Double barrier isolation, that is to say two barriers in series, are generally necessary for containing pressure in a well. If a spool tree is used instead of a conventional Christmas tree, there are no valves within the vertical production and annulus fluid flow bores within the tree, and alternative provision must be made for sealing the bore or bores through the top of the spool tree which provide for wire line or drill pipe access.

In accordance with a further feature of the invention, at least one vertical production fluid bore in the tubing hanger is sealed above the respective lateral production fluid outlet port by means of a removable plug, and the bore through the spool tree being sealed above the tubing hanger by means of a second removable plug.

With this arrangement, the first plug, takes the function of a conventional swab valve, and may be a wireline set plug. The second plug could be a stopper set in the spool tree above the tubing hanger by, e.g., a drill pipe running tool. The stopper could contain at least one wireline retrievable plug which would allow well access when only wire line operations are called for. The second plug should seal and be locked internally into the spool tree as it performs a barrier to the well when a BOP or intervention module is deployed. A particular advantage of this double plug arrangement is that, as is necessary to satisfy authorities in some jurisdictions, the two independent barriers are provided in mechanically separate parts, namely the tubing hanger and its plug and the second plug in the spool tree.

A further advantage arises if a workover port extends laterally through the wall of the spool tree from between the two plugs; a tubing annulus fluid port extends laterally through the wall of the spool tree from the tubing annulus; and these two ports through the spool tree are interconnected via an external flow line containing at least one actuated valve. The bore from the tubing annulus can then terminate at the port in the spool tree and no wireline access to the tubing annulus bore is necessary through the spool tree as the tubing annulus bore can be connected via the interplug void to choke or kill lines, i.e. a BOP annulus, so that downhole circulation is still available. It is then only necessary to provide wireline access at workover situations to the production bore or bores. This considerably simplifies workover BOP and/or riser construction. When used in conjunction with the plug at the top of the spool tree, the desirable double barrier isolation is provided by the spool tree plug over the tubing hanger, or workover valve from the production flow.

When the well is completed as a multi production bore well, in which the tubing hanger has at least two vertical production through bores each with a lateral production fluid flow port aligned with the corresponding port in the spool tree, at least two respective connectors may be provided for selective connection of a single bore wire line running tool to one or other of the production bores, each connector having a key for entering a complementary formation at the top of the spool tree to locate the connector in a predetermined angular orientation relatively to the spool tree. The same type of alternative connectors may be used for providing wireline or other running tool access to a selected one of a plurality of functional connections, e.g. electrical or hydraulic couplings, at the upper end of the tubing hanger.

The development and completion of a subsea wellhead in accordance with the present invention are illustrated in the accompanying drawings, in which:

FIGS. 1 to 8 are vertical axial sections showing successive steps in development and completion of the wellhead, the Figure numbers bearing the letter A being enlargements of part of the corresponding Figures of same number without the A:

FIG. 9 is a circuit diagram showing external connections to the spool 3;

FIG. 10 is a vertical axial section through a completed dual production bore well in production mode;

FIGS. 11 and 12 are vertical axial sections showing alternative connectors to the upper end of the dual production bore wellhead during work over; and,

FIG. 13 is a detail showing the seating of one of the connectors in the spool tree.

FIG. 1 shows the upper end of a cased well having a wellhead housing 20, in which casing hangers, including an uppermost production casing hanger 21 for, for example, 9 ⅝" or 10 ¾", production casing is mounted in conventional manner. FIG. 1 shows a conventional drilling BOP 22 having rams 23 and kill and choke lines 24 connected to the upper end of the housing 20 by a drilling connector 25.

As seen in more detail in FIG. 1A, the usual mechanical seal assemblies between the production casing hanger 21 and the surrounding wellhead housing 20 have been removed and replaced through the BOP with an adapter 26 consisting of an outer annular body part 27 and an inner annular gland nut 28 which has a screw threaded connection to the body 27 so that it can be screwed between a lowered position shown on the right hand side of FIG. 1A, in which radial ducts 29 and 30, respectively in the body 27 and nut 28, are in communication with one another, and a raised position shown on the left hand side of FIG. 1A, in which the ducts are out of communication with one another. The duct 29 communicates through a conduit 31 between a depending portion of the body 27 and the housing 20, and through a conduit 32 passing through the production casing hanger 21, to the annulus surround the production casing. The duct 30 communicates through channels 33 formed in the radially inner surface of the nut 28, and hence to a void to be described. The cooperation between the gland nut 28 and body 27 of the adapter therefore acts as a valve which can open and close a passage up past the production casing hanger from the production casing annulus. After appropriate testing, a tool is run in through the BOP and, by means by radially projecting spring lugs engaging in the channels 33, rotates the gland nut 28 to the valve closed position shown on the right hand side on FIG. 1A. The well is thus resealed and the drilling BOP 22 can temporarily be removed.

As shown in FIGS. 2 and 2A, the body of a tree spool 34 is then lowered on a tree installation tool 35, using conventional guide post location, or a guide funnel in case of deep water, until a spool tree mandrel 36 is guided into alignment with and slides as a close machined fit, into the upper end of the wellhead housing 20, to which the spool tree is then fixed via a production connector 37 and bolts 38. The mandrel 36 is actually a separate part which is bolted and sealed to the rest of the spool tree body. As seen particularly in FIG. 2A a weight set AX gasket 39, forming a metal to metal environmental seal is provided between the spool tree body and the wellhead housing 20. In addition two sets of sealing rings 40 provide, in series with the environmental seal, a production fluid seal externally between the ends to the spool tree mandrel 36 to the spool tree body and to the wellhead housing 20. The intervening cavity can be tested through a test ports 40A. The provision of the adapter 26 is actually optional, and in its absence the lower end of the spool tree mandrel 36 may form a production seal directly with the production casing hanger 21. As is also apparent from reasons which will subsequently become apparent, the upper radially inner edge of the spool tree mandrel projects radially inwardly from the inner surface of the spool tree body above, to form a landing shoulder 42 and at least one machined key slot 43 is formed down through the landing shoulder.

As shown in FIG. 3, the drilling BOP 22 is reinstalled on the spool tree 34. The tool 44 used to set the adapter in FIG. 1, having the spring dogs 41, is again run in until it lands on the shoulder 42, and the spring dogs 41 engage in the channels 33. The tool is then turned to screw the gland nut 28 down within the body 27 of the adapter 26 to the valve open position shown on the right hand side in FIG. 1A. It is now safe to open the production casing annulus as the well is protected by the BOP.

The next stage, shows in FIGS. 4 and 4A, is to run in through the BOP and spool tree on an appropriate tool 44A a combined isolation and orientation sleeve 45. This lands on the shoulder 42 at the top of the spool tree mandrel and is rotated until a key on the sleeve drops into the mandrel key slot 43. This ensures precise angular orientation between the sleeve 45 and the spool tree 44, which is necessary, and in contrast to the angular orientation between the spool tree 34 and the wellhead casing, which is arbitrary. The sleeve 45 consists of an external cylindrical portion, an upper external surface of which is sealed by ring seals 46 to the spool tree 34, and the lower external surface of which is sealed by an annular seal 47 to the production casing hanger 21. There is thus provided between the sleeve 45 and the surrounding wellhead casing 20 a void 48 with which the channels 33, now defined radially inwardly by the sleeve 45, communicate. The void 48 in turn communicates via a duct 49 through the mandrel and body of the spool tree 34 to a lateral port. It is thus possible to monitor and vent the pressure in the production casing annulus through the passage provided past the production casing hanger via the conduits 32, 31 the ducts 29 and 30, the channels 33, shown in FIG. 1A, the void 48, the duct 49, and the lateral port in the spool tree. In the drawings, the radial portion of the duct 49 is shown apparently communicating with a tubing annulus, but this is draughtsman's licence and the ports from the two annuli are, in fact, angularly and radially spaced.

Within the cylindrical portion of the sleeve 45 is a lining, which may be fixed in the cylindrical portion, or left after internal machining of the sleeve. This lining provides an orientation sleeve having an upper/edge forming a cam 50. The lowermost portion of the cam leads into a key slot 51.

As shown in FIGS. 5,6 and 6A a tubing string of production tubing 53 on a tubing hanger 54 is run in through the BOP 22 and spool tree 34 on a tool 55 until the tubing hanger lands by means of a keyed shoulder 56 on a landing in the spool tree and is locked down by a conventional mechanism 57. The tubing hanger 54 has a depending orientation sleeve 58 having an oblique lower edge forming a cam 59 which is complementary to the cam 50 in the sleeve 45 and, at the lower end of the cam, a downwardly projecting key 60 which is complementary to the key slot 51. The effect of the cams 50 and 59 is that, irrespective of the angular orientation of the tubing string as it is run in, the cams will cause the tubing hanger 54 to be rotated to its correct angular orientation relatively to the spool tree and the engagement of the key 60 in the key slot 51 will lock this relative orientation between the tubing hanger and spool tree, so that lateral production and tubing annulus fluid flow ports 61 and 62 in the tubing hanger 54 are in alignment with respective lateral production and tubing annulus fluid flow ports 63 and 64 through the wall of the spool tree. Metal to metal annulus seals 65, which are set by the weight of the tubing string, provide production fluid seals between the tubing hanger 54 and the spool tree 34. Provision is made in the top of the tubing hanger 54 for a wireline set plug 66. The keyed shoulder 56 of the tubing hanger lands in a complementary machined step in the spool tree 34 to ensure ultimate machined accuracy of orientation between the tubing hanger 54 and the spool tree 34.

FIG. 7 shows the final step in the completion of the spool tree. This involves the running down on drill pipe 67 through the BOP, an internal isolation stopper 68 which seals within the top of the spool tree 34 and has an opening closed by an in situ wireline activated plug 69. The BOP can then be removed leaving the wellhead in production mode with double barrier isolation at the upper end of the spool tree provided by the plugs 66 and 69 and the stopper 68. The production fluid outlet is controlled by a master control valve 70 and pressure through the tubing annulus outlet ports 62 and 64 is controlled by an annulus master valve 71.

The other side of this valve is connected, through a workover valve 72 to a lateral workover port 73 which extends through the wall of the spool tree to the void between the plugs 69 and 66. With this arrangement, wireline access to the tubing annulus in and downstream of a tubing hanger is unnecessary as any circulation of fluids can take place through the valves 71 and 72, the ports 62, 64 and 73, and the kill or choke lines of any BOP which has been installed. The spool tree in the completed production mode is shown in FIG. 8.

FIG. 9 shows valve circuitry associated with the completion and, in addition to the earlier views, shows a production fluid isolation valve 74, a tubing annulus valve 75 and a cross over valve 76. With this arrangement a wide variety of circulation can be achieved down hole using the production bore and tubing annulus, in conjunction with choke and kill lines extending from the BOP and through the usual riser string. All the valves are fail/safe closed if not actuated.

The arrangement shown in FIGS. 1 to 9 is a mono production bore wellhead which can be accessed by a single wireline or drill pipe, and the external loop from the tubing annulus port to the void between the two plugs at the top of the spool, tree avoids the need for wireline access to the tubing annulus bore.

FIG. 10 corresponds to FIG. 8 but shows a 5½ inch×2⅜ inch dual production bore wellhead with primary and secondary production tubing 53A and 53B. Development and completion are carried out as with the monobore wellhead except that the spool tree 34A and tubing hanger 54A are elongated to accommodate lateral outlet ports 61A, 63A for the primary production fluid flow from a primary bore 80 in the tubing hanger to a primary production master valve 70A, and lateral outlet ports 62A, 64A for the secondary production fluid flow from a secondary bore 81 in the tubing hanger to a secondary production master valve 70B. The upper ends of the bores 80 and 81 are closed by wireline plugs 66A and 66B. A stopper 68A, which closes the upper end of the spool tree 34A has openings, in alignment with the plugs 66A and 66B, closed by wireline plugs 69A and 69B.

FIGS. 11 and 12 show how a wireline 77 can be applied through a single drill pipe to activate selectively one or other of the two wireline plugs 66A and 66B in the production bores 80 and 81 respectively. This involves the use of a selected one of two connectors 82 and 83. In practice, a drilling BOP 22 is installed and the stopper 68A is removed. Thereafter the connector 82 or 83 is run in on the drill pipe or tubing until it lands in, and is secured and sealed to the spool tree 34A. FIG. 13 shows how the correct angular orientation between the connector 82 or 83 and the spool tree 34A, is achieved by wing keys 84, which are guided by Y-shaped slots 85 in the upper inner edge of the spool tree, first to bring the connectors into the right angular orientation, and then to allow the relative axial movement between the parts to enable the stabbing function when the wireline connector engages with its respective pockets above plug 66A or 66B. To ensure equal landing forces and concentricity on initial contact, two keys 84A and 84B are recommended. As the running tool is slowly rotated under a new control weight, it is essential that the tool only enters in one fixed orientation. To ensure this key 84A is wider than key 84B and its respective Y-shaped slots. It will be seen that one of the connectors 82 has a guide duct 86 which leads the wireline to the plug 66B whereas the other connector 83 has a similar guide duct 87 which leads the wireline to the other plug 66A.

We claim:

1. A wellhead assembly for supporting tubing within a well for selective use with a blowout preventer having a BOP bore comprising:

a housing;

a spool tree adapted for disposal below the blowout preventer and fixed and sealed to said housing, said spool tree having a wall with a central bore therethrough and a first lateral port connected to a valve, said central bore having an internal surface and adapted to form a common passageway with the BOP bore;

a tubing hanger landed and sealed within said spool tree at a predetermined angular position at which a second lateral port in said tubing hanger is in alignment with said first lateral port in said spool tree, said tubing hanger supporting the tubing;

at least one vertical bore in said tubing hanger being sealed above said second lateral port by a first closure member, and said internal surface of said central bore through said spool tree being sealed above said tubing hanger by a second closure member, said closure members being retrievable through the BOP bore;

a workover port extending through said wall of said spool tree for selective fluid circulation with that portion of said common passageway below the BOP bore and above said tubing hanger; and

an annulus port extending through said wall of said spool tree for selective fluid circulation with an annulus around the tubing, said workover and annulus ports being interconnected via a flow passageway having at least one valve.

2. The wellhead assembly of claim 1 further comprising a bypass flowpath extending from said annulus port, through said flow passageway and said workover port, to said central bore above said tubing hanger.

3. The wellhead assembly of claim 1, further comprising a crossover flowpath interconnecting said first lateral port and said flow passageway, said crossover flowpath having a crossover valve for controlling flow therethrough.

4. The wellhead assembly of claim 3 further comprising a first combined workover flowpath extending from said annulus port, through said flow passageway and said crossover flowpath, to said first lateral port.

5. The wellhead assembly of claim 3 further comprising a second combined workover flowpath extending from said workover port, through said flow passageway and said crossover flowpath, to said first lateral port.

6. The wellhead assembly of claim 1 wherein said central bore has an inside diameter substantially the same as the diameter of the BOP bore.

7. An apparatus for use selectively with a blowout preventer for controlling the flow of fluids in a well comprising:

a production member adapted for disposal below the blowout preventer, said production member having a central bore formed by a wall of said production member and a production passageway, an annulus passageway, and a workover passageway in said wall, said workover passageway extending laterally into said central bore;

a production valve disposed with said production member for controlling flow through said production passageway;

an annulus valve disposed with said production member for selective fluid circulation downhole through said annulus passageway;

a workover valve disposed with said production member for selective fluid circulation through said workover passageway;

a tubing hanger supported and sealed within said production member and suspending tubing in the well, said

tubing hanger and tubing having a flowbore and forming an annulus in the well, said tubing hanger having an aperture communicating said flowbore with said production passageway, and said annulus passageway communicating with said annulus;

said workover passageway in fluid communication with said production member central bore above said tubing hanger;

said annulus passageway in fluid communication with said workover passageway;

said production passageway in fluid communication with said annulus passageway and workover passageway;

a crossover valve for controlling fluid flow between said production passageway and said annulus passageway or workover passageway; and

fluid circulation paths being formed between said production member central bore, workover passageway, and annulus passageway to selectively circulate downhole using said tubing flowbore and tubing annulus.

8. The apparatus of claim 7 further including a production fluid isolation valve communicating with said production passageway and an annulus isolation valve communicating with said annulus passageway.

9. A method for controlling fluid flow in a well comprising:

suspending tubing from a tubing hanger;

supporting and sealing the tubing hanger within the bore of a production member for selective disposal below a blowout preventer having a BOP bore;

forming a common flow passageway between the BOP bore and a portion of the production member bore above the seals around the tubing hanger;

extending a tubular member into the BOP bore, attaching the tubular member to the tubing hanger, and closing the blowout preventer therearound;

forming a flowpath through the tubing and the tubular member, forming an annular area between the tubular member and the production member in the common flow passageway and forming an annulus around the tubing below the tubing hanger;

forming a production passageway from the flowpath, through a lateral port in the tubing hanger and through the wall of the production member;

controlling flow through the production passageway by a production valve;

forming an annulus passageway from the annulus and through the wall of the production member;

controlling flow through the annulus passageway by an annulus valve;

forming a workover passageway from the annular area and through the wall of the production member;

controlling flow through the workover passageway;

providing fluid communication between the workover passageway and the annulus passageway;

forming a crossover fluid passageway between the production passageway and annulus passageway;

controlling flow through the crossover fluid passageway; and

circulating fluid downhole using the flowpath, tubing annulus, annulus passageway, workover passageway, and annular area.

10. The method of claim 9 further including flowing fluid downhole through the workover passageway, the crossover passageway, and the production passageway.

11. A method for controlling fluid flow in a well comprising:

suspending tubing from a tubing hanger;

supporting and sealing the tubing hanger within the bore of a production member for selective disposal below a blowout preventer having a BOP bore;

forming a common flow passageway between the BOP bore and a portion of the production member bore above the tubing hanger;

extending a tubular member into the BOP bore, attaching and sealing the tubular member to the tubing hanger, and closing the blowout preventer therearound with the tubular member in fluid communication with said tubing flowbore;

forming a flowbore through the tubing, an annulus around the tubing below the tubing hanger, and an annular area between the tubular member and production member in the common flow passageway;

forming a production passageway from the flowbore, through a lateral port in the tubing hanger and through the wall of theproduction member;

controlling flow through the production passageway by a production valve;

forming an annulus passageway from the annulus and through the wall of the production member;

controlling flow through the annulus passageway by an annulus valve;

forming a workover passageway communicating with the annular area through the wall of the production member;

controlling flow through the workover passageway;

providing fluid communication between the workover passageway and annulus passageway;

forming a crossover fluid passageway between the production passageway and annulus passageway;

controlling flow through the crossover fluid passageway;

installing a tubing hanger closure member in the tubing hanger above the production passageway;

removing the tubular member; and

flowing fluid through the production passageway, through the crossover passageway and into the annulus passageway.

12. A method for controlling fluid flow in a well comprising:

suspending tubing from a tubing hanger;

supporting and sealing the tubing hanger within the bore of a production member for selective disposal below a blowout preventer having a BOP bore;

forming a common flow passageway between the BOP bore and a portion of the production member bore above the tubing hanger;

forming a flowbore through the tubing and an annulus around the tubing below the tubing hanger;

forming a production passageway from the flowbore, through a lateral port in the tubing hanger and through the wall of the production member;

controlling flow through the production passageway by a production valve;

forming an annulus passageway from the annulus and through the wall of the production member;

controlling flow through the annulus passageway by an annulus valve;

installing a tubing hanger closure member in the tubing hanger above the production passageway;

installing an internal closure member within the portion of the production member bore above the tubing hanger;

forming a workover passageway through the wall of the production member from the bore of the production member above the tubing hanger and between the tubing hanger closure member and internal closure member;

controlling flow through the workover passageway;

forming a crossover fluid passageway between the production passageway and annulus passageway;

controlling flow through the crossover fluid passageway;

providing fluid communication between the workover passageway and the crossover fluid passageway; and

flowing fluid through the production passageway, through the crossover passageway and into the workover passageway between the tubing hanger closure member and the internal closure member.

13. An assembly for producing a well comprising:

a wellhead supporting a casing hanger that suspends casing which forms a casing annulus;

a pressure monitoring valve disposed within said wellhead on said casing hanger and connected to a passageway extending to the casing annulus for monitoring the pressure in the casing annulus;

a spool tree mandrel projecting into said wellhead and disposed on said pressure monitoring valve;

a completion tree connected to said wellhead;

a drilling blowout preventer connected to said completion tree;

said wellhead, completion tree and blowout preventer forming a common bore;

said completion tree having a master horizontal bore, an annulus horizontal bore, and a workover bore;

a production master valve connected to said master horizontal bore;

an annulus master valve connected to said annulus horizontal bore;

a workover valve connected to said workover bore;

a pressure monitoring port extending through said completion tree and spool tree mandrel and communicating with an annular space above said pressure monitoring valve;

an orientation sleeve associated with said spool tree mandrel and having an orienting cam surface;

a tubing hanger lowerable through said common bore and having a side master port and a side annulus port, said tubing hanger having an orienting cam member engaging said orienting cam surface to align said side master and annulus ports with said master and annulus horizontal bores in said completion tree;

said tubing hanger suspending tubing within said casing and forming a tubing annulus;

a tubing hanger plug disposed in said tubing hanger for plugging said tubing hanger above said side master port;

an isolation member mounted at least partially within said completion tree above said tubing hanger and having a central bore;

an isolation plug disposed within said isolation member for plugging said central bore;

a cover disposed on said isolation member and covering said common bore; and

said workover bore communicating with said common bore between said tubing hanger plug and said isolation plug.

14. A spool tree assembly for use selectively with a blowout preventer for operating a subsea well, comprising:

a spool body adapted for disposal below the blowout preventer and having a central bore therethrough, a portion of said central bore being formed by an internal generally vertical wall surface, said internal generally vertical wall surface having an opening therein;

a tubing hanger assembly mounted and sealed in a predetermined angular position within said central bore of said spool body and suspending tubing within the well, said tubing hanger assembly and tubing forming a central passageway therethrough and an annulus around the tubing below the tubing hanger;

said spool body and said tubing hanger assembly having a production passageway extending from said central passageway of said tubing hanger assembly into said wall of said spool body;

said spool body and said tubing hanger assembly having an annulus passageway extending from said annulus around the tubing below the tubing hanger and into said wall of said spool body;

said spool body having a workover passageway extending from said opening in said central bore and into said spool body wall, said opening in fluid communication with said central bore above the tubing hanger; and

said annulus passageway and workover passageway being in fluid communication through a flowpath to selectively circulate downhole from said central bore of said spool body through said workover passageway and annulus passageway with flow through said tubing hanger assembly annulus and central passageway of said tubing hanger assembly.

15. The spool tree assembly of claim 14 further comprising a closure member sealingly disposed within said central bore of said spool body to control flow through said central bore.

16. A spool tree assembly for use selectively with a blowout preventer having a BOP bore for operating a subsea well, comprising:

a spool body adapted for disposal below the blowout preventer and having a generally cylindrical wall forming a central bore therethrough, a portion of said central bore being adapted to form a flow passageway with the BOP bore;

a tubing hanger assembly mounted and sealed within said central bore of said spool body and suspending tubing within the well said tubing hanger and tubing forming a central passageway in fluid communication with said central bore of said spool body above said tubing hanger assembly and forming an annulus around the tubing below the tubing hanger;

said spool body and said tubing hanger assembly having a production passageway extending from said central passageway of said tubing hanger assembly into said wall of said spool body;

said spool body and said tubing hanger assembly having an annulus passageway extending from said annulus around the tubing below the tubing hanger and into said wall of said spool body;

said spool body having a workover passageway extending from said portion of said central bore of said spool body and into said spool body wall for fluid communication

with said portion of said spool body central bore above said tubing hanger;

said annulus passageway and workover passageway being in fluid communication through a flowpath outside of said central bore of said spool body;

a first closure member mounted within said central passageway of said tubing hanger assembly to control flow through said central passageway and through said central bore of said spool body; and

a second closure member sealed and locked internally of said portion of said central bore above said tubing hanger assembly.

17. The spool tree assembly of claim 16 wherein said workover passageway is in fluid communication with said portion of said central bore between said first and second closure members.

18. A wellhead for supporting tubing for use selectively with a blowout preventer having a BOP bore comprising:

a wellhead housing;

a spool tree adapted for disposal below the blowout preventer and fixed and sealed to said housing, said spool tree having a wall with a central bore therethrough and at least a first lateral production fluid outlet port connected to a valve, a portion of said central bore being adapted to form a common passageway with the BOP bore;

a tubing hanger supporting the tubing and landed and sealed within said spool tree at a predetermined angular position at which a second lateral production fluid outlet port in said tubing hanger is in alignment with said first lateral production fluid outlet port in said spool tree;

at least one vertical production fluid bore in said tubing hanger being sealed above said second lateral production fluid outlet port by a first removable closure member, and said portion of said central bore through said spool tree being internally sealed above said tubing hanger by a second closure member removable through the BOP bore;

a workover port extending at least partially through said wall of said spool tree from an area in said portion of said central bore between said two closure members; and

a tubing annulus fluid port extending at least partially through said wall of said spool tree from an annulus formed around the tubing; said workover and tubing annulus ports in said spool tree being interconnected via a passageway having at least one valve.

19. A spool tree system for use selectively with a blowout preventer having a BOP bore for a subsea well, comprising:

a spool tree having a bore therethrough, a portion of said bore being adapted to form a flow passageway with the BOP bore upon installing the blowout preventer above said spool tree;

a tubing hanger suspending tubing and supported by said spool tree, seals sealing between said tubing hanger and said spool tree, said tubing hanger and tubing having an internal production bore extending downwardly into the well and forming a tubing annulus extending downwardly into the well;

said spool tree and tubing hanger forming a lateral production flowpath in fluid communication with said internal production bore and having a production control valve for opening and closing said lateral production flowpath to control flow therethrough;

said spool tree forming an annulus flowpath in fluid communication with said tubing annulus and having an annulus control valve controlling flow therethrough;

said spool tree having a workover flowpath through the wall of the spool tree communicating with said portion of said spool tree bore above said seals and having a workover valve controlling flow therethrough;

a circulation flowpath being formed through said internal production bore of said tubing hanger with said lateral production flowpath closed and through said tubing annulus to selectively circulate fluid downhole using said internal production bore and said tubing annulus; and

said internal production bore above said lateral production flowpath being adapted for isolation from said spool tree bore portion.

20. The spool tree system of claim 19, further comprising:

a first closure member mounted in said tubing hanger; and,

a second closure member sealably mounted completely internal of said portion of said bore of said spool tree.

21. The spool tree system of claim 20, wherein a fluid passageway is formed above said first closure member for selective fluid circulation.

22. The spool tree system of claim 20 wherein said workover flowpath terminates in said portion of said spool tree bore between said first and second closure members.

23. The spool tree system of claim 19, further including a first external flowpath with a tubing annulus valve for controlling flow therethrough, a second extena flowpath with a production fluid isolation valve for controlling flow therethrough, and a fluid passageway formed between said first and second external flowpaths by said annulus flowpath, tubing annulus, production bore, and production flowpath.

24. A spool tree system for use selectively with a blowout preventer having a BOP bore, a tubular member extending through the BOP bore and having a fluid bore, and a wellhead for a subsea well, comprising:

a spool tree for installation on the wellhead, said spool tree having a wall with a bore therethrough, a portion of said bore being adapted to form a flow passageway with the BOP bore upon installation of the blowout preventer above said spool tree;

a tubing hanger suspending tubing and supported by said spool tree, seals sealing between said tubing hanger and said spool tree, said tubing hanger and tubing having an internal production bore and forming a tubing annulus extending downwardly into the well, said internal production bore adapted for connection with the tubular member for fluid communication with the fluid bore of the tubular member;

said spool tree and tubing hanger forming a lateral production flowpath in fluid communication with said internal production bore and having a production control valve controlling flow therethrough;

said spool tree forming an annulus flowpath in fluid communication with said tubing annulus and having an annulus control valve controlling flow therethrough;

said spool tree having a workover flowpath through the wall of the spool tree communicating with said portion of said spool tree bore above said seals and having a workover valve controlling flow therethrough;

a circulation flowpath being formed upon establishing fluid communication between said internal production bore of said tubing hanger and tubing and fluid bore of

said tubular member, said circulation flowpath allowing flow through said internal production bore of said tubing hanger and tubing and fluid bore of said tubular member and through said annulus and annulus flowpath for selective fluid circulation through said circulation flowpath;

a workover/annulus flow connection interconnecting said workover flowpath and said annulus flowpath for selective fluid circulation downhole through said circulation flowpath and said workover flowpath to an annular area formed between the tubular member and spool tree bore.

25. The spool tree system of claim 24 further comprising a bypass flowpath extending from said annulus flowpath, through said workover/annulus flow connection and said workover flowpath, to said portion of said spool tree bore.

26. The spool tree system of claim 24, further comprising a crossover flowpath interconnecting said production flowpath and said workover/annulus flow connection, said crossover flowpath having a crossover valve for controlling flow therethrough.

27. The spool tree system of claim 26 further comprising a first combined workover flowpath extending from said annulus flowpath, through said workover/annulus flow connection and said crossover flowpath, to said production flowpath.

28. The spool tree system of claim 26 further comprising a second combined workover flowpath extending from said workover flowpath, through said workover/annulus flow connection and said crossover flowpath, to said production flowpath.

29. A spool tree system for a wellhead for the completion and work-over of a subsea well, comprising:

a spool tree having a bore and for installation on the wellhead;

a tubing hanger suspending tubing and supported by said spool tree, seals sealing between said tubing hanger and said spool tree, said tubing having an internal production bore and forming a tubing annulus extending downwardly into the well;

said spool tree and tubing hanger forming a production flowpath in fluid communication with said internal production bore and having a production control valve controlling flow therethrough;

said spool tree forming an annulus flowpath in fluid communication with said tubing annulus and having an annulus control valve controlling flow therethrough;

a drilling blowout preventer having a BOP bore and a member for closing said BOP bore, a portion of said spool tree bore adapted to form a flow passageway with said BOP bore;

said spool tree having a workover flowpath communicating with said spool tree bore portion above said seals and below said BOP bore and having a workover valve controlling flow therethrough;

choke and kill lines connected to said drilling blowout preventer for communicating said BOP bore with the surface; and

a tubular member extending to the surface and in fluid communication with said tubing hanger, said tubular member forming a common bore communicating with said internal production bore for selective fluid circulation downhole using said internal production bore and tubing annulus in conjunction with at least one of said choke and kill lines extending from the BOP to the surface.

30. The spool tree system of claim 29, wherein one of said choke and kill lines forms a passageway from the surface to said BOP bore above said tubing hanger.

31. The spool tree system of claim 29 further comprising a workover/annulus flow connection interconnecting said workover flowpath and said annulus flowpath for selective fluid communication.

32. The spool tree system of claim 31, further comprising a crossover flowpath interconnecting production flowpath and said workover/annulus flow connection, said crossover flowpath having a crossover valve for controlling flow therethrough.

33. A spool tree system for a wellhead for the completion and work-over of a subsea well, comprising:

a spool tree having a bore and for installation on the wellhead;

a tubing hanger suspending tubing and supported by said spool tree, seals sealing between said tubing hanger and said spool tree, said tubing having an internal production bore and forming a tubing annulus extending downwardly into the well;

said spool tree and tubing hanger forming a production flowpath in fluid communication with said internal production bore and having a production control valve controlling flow therethrough;

said spool tree forming an annulus flowpath in fluid communication with said tubing annulus and having an annulus control valve controlling flow therethrough;

a drilling blowout preventer having a BOP bore and a member for closing said BOP bore, a portion of said spool tree bore adapted to form a flow passageway with said BOP bore;

said spool tree having a workover flowpath communicating with said spool tree bore portion above said seals and below said BOP bore and having a workover valve controlling flow therethrough;

choke and kill lines connected to said drilling blowout preventer for communicating said BOP bore with the surface;

a pipe string extending to the surface and in fluid communication with said tubing hanger, said pipe string forming a common bore communicating with said internal production bore;

a workover/annulus flow connection interconnecting said workover flowpath and said annulus flowpath; and

a fluid passageway to the surface being formed by said common bore, production bore, tubing annulus, annulus flowpath, workover/annulus flow connection, workover flowpath, BOP bore, and one of said choke and kill lines.

34. A spool tree system for a wellhead for the completion and work-over of a subsea well, comprising:

a spool tree having a bore and for installation on the wellhead;

a tubing hanger suspending tubing and supported by said spool tree, seals sealing between said tubing hanger and said spool tree, said tubing having an internal production bore and forming a tubing annulus extending downwardly into the well;

said spool tree and tubing hanger forming a production flowpath in fluid communication with said internal production bore and having a production control valve controlling flow therethrough;

said spool tree forming an annulus flowpath in fluid communication with said tubing annulus and having an annulus control valve controlling flow therethrough;

a drilling blowout preventer having a BOP bore and a member for closing said BOP bore, a portion of said spool tree bore adapted to form a flow passageway with said BOP bore;

said spool tree having a workover flowpath communicating with said spool tree bore portion above said seals and below said BOP bore and having a workover valve controlling flow therethrough;

choke and kill lines connected to said drilling blowout preventer for communicating said BOP bore with the surface;

a workover/annulus flow connection interconnecting said workover flowpath and said annulus flowpath;

a pipe string extending to the surface and in fluid communication with said tubing hanger, said pipe string forming a common bore communicating with said internal production bore;

a crossover flowpath interconnecting said production flowpath and said workover/annulus flow connection said crossover flowpath having a crossover valve for controlling flow therethrough; and

a fluid passageway being formed by said common bore, internal production bore, tubing annulus, annulus flowpath, workover/annulus flow connection, crossover flowpath, and production flowpath.

35. A spool tree system for a wellhead for the completion and work-over of a subsea well, comprising:

a spool tree having a bore and for installation on the wellhead;

a tubing hanger suspending tubing and supported by said spool tree, seals sealing between said tubing hanger and said spool tree, said tubing having an internal production bore and forming a tubing annulus extending downwardly into the well;

said spool tree and tubing hanger forming a production flowpath in fluid communication with said internal production bore and having a production control valve controlling flow therethrough;

said spool tree forming an annulus flowpath in fluid communication with said tubing annulus and having an annulus control valve controlling flow therethrough;

a drilling blowout preventer having a BOP bore and a member for closing said BOP bore, a portion of said spool tree bore adapted to form a flow passageway with said BOP bore;

said spool tree having a workover flowpath communicating with said spool tree bore portion above said seals and below said BOP bore and having a workover valve controlling flow therethrough;

choke and kill lines connected to said drilling blowout preventer for communicating said BOP bore with the surface;

a workover/annulus flow connection interconnecting said workover flowpath and said annulus flowpath;

a pipe string extending to the surface and in fluid communication with said tubing hanger, said pipe string forming a common bore communicating with said internal production bore;

a crossover flowpath interconnecting said production flowpath and said workover/annulus flow connection, said crossover flowpath having a crossover valve for controlling flow therethrough; and

a fluid passageway being formed by one of said choke and kill lines, workover flowpath, workover/annulus flow connection, crossover flowpath, production flowpath, and common bore.

36. A spool tree system for a wellhead for the completion and work-over of a subsea well, comprising:

a spool tree having a bore and for installation on the wellhead;

a tubing hanger suspending tubing and supported by said spool tree, seals sealing between said tubing hanger and said spool tree, said tubing having an internal production bore and forming a tubing annulus extending downwardly into the well;

said spool tree and tubing hanger forming a production flowpath in fluid communication with said internal production bore and having a production control valve controlling flow therethrough;

said spool tree forming an annulus flowpath in fluid communication with said tubing annulus and having an annulus control valve controlling flow therethrough;

a drilling blowout preventer having a BOP bore and a member for closing said BOP bore, a portion of said spool tree bore adapted to form a flow passageway with said BOP bore;

said spool tree having a workover flowpath communicating with said spool tree bore portion above said seals and below said BOP bore and having a workover valve controlling flow therethrough;

choke and kill lines connected to said drilling blowout preventer for communicating said BOP bore with the surface;

a pipe string extending to the surface and in fluid communication with said tubing hanger, said pipe string forming a common bore communicating with said internal production bore;

a workover/annulus flow connection interconnecting said workover flowpath and said annulus flowpath; and

said member being closed around said pipe string and further comprising a fluid passageway extending from the surface to the BOP bore through one of said choke and kill lines, another fluid passageway extending from the surface through said common bore, internal production bore, tubing annulus, annulus flowpath, workover/annulus flow connection, and workover flowpath to the BOP bore, and the other of said choke and kill lines extending from the BOP bore to the surface.

37. A spool tree assembly for use selectively with a blowout preventer having a BOP bore for operating a subsea well, comprising:

a spool body adapted for disposal below the blowout preventer and having a generally cylindrical internal wall forming a spool body central bore therethrough, a portion of said central bore being adapted to form a flow passageway with the BOP bore;

a tubing hanger assembly mounted in said spool body central bore and having a central passageway with a production passageway extending from said tubing hanger central passageway, an annulus being formed around said tubing hanger assembly;

said internal wall of said spool body having a production port in fluid communication with said production passageway, an annulus port in fluid communication with said annulus, and a workover port in fluid communication with said portion of said spool body central bore above said production passageway; and

said annulus port and said workover port being in fluid communication externally of said spool body central bore.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,039,119
DATED : March 23, 2000
INVENTOR(S) : Hans Paul Hopper, et al.

It is certified that error appears in the above-indentified patent and that said Letters Patent is hereby corrected as shown below:

Column 5, Line 64 change "shows" to --shown--;

Column 7, Line 22 after "spool" delete --,--;

Column 10, Line 22 change "theproducfion" to --the production--;

Column 14, Line 31 change "extena" to --external--; and

Column 16, Line 9 after "interconnecting" insert --said--.

Signed and Sealed this

Twenty-seventh Day of March, 2001

Attest:

Nicholas P. Godici

NICHOLAS P. GODICI

Attesting Officer

Acting Director of the United States Patent and Trademark Office

EXHIBIT C

US006547008B1

(12) **United States Patent**
Hopper et al.

(10) **Patent No.: US 6,547,008 B1**
(45) **Date of Patent: *Apr. 15, 2003**

(54) **WELL OPERATIONS SYSTEM**

(75) Inventors: **Hans Paul Hopper**, Aberdeen (GB); **Thomas G. Cassity**, Tyronos Sandy Lane Cobham (GB)

(73) Assignee: **Cooper Cameron Corporation**, Houston, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **09/657,018**

(22) Filed: **Sep. 7, 2000**

Related U.S. Application Data

(63) Continuation of application No. 09/092,549, filed on Jun. 5, 1998, now abandoned, which is a division of application No. 08/679,560, filed on Jul. 12, 1996, now Pat. No. 6,039,119, which is a continuation of application No. 08/204,397, filed as application No. PCT/US93/05246 on May 28, 1993, now Pat. No. 5,544,707.

(30) **Foreign Application Priority Data**

Jun. 1, 1992 (EP) 92305014

(51) **Int. Cl.**[7] **E21B 33/03**

(52) **U.S. Cl.** **166/348**; 166/88.4; 166/95.1; 166/368

(58) **Field of Search** 166/348, 368, 166/379, 88.4, 89.1, 88.1, 95.1

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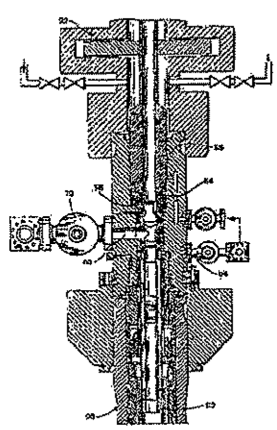
Primary Examiner—Hoang Dang
(74) *Attorney, Agent, or Firm*—Conley Rose, P.C.

(57) **ABSTRACT**

A wellhead has, instead of a conventional Christmas tree, a spool tree (34) in which a tubing hanger (54) is landed at a predetermined angular orientation. As the tubing string can be pulled without disturbing the tree, many advantages follow, including access to the production casing hanger (21) for monitoring production casing annulus pressure, and the introduction of larger tools into the well hole without breaching the integrity of the well.

23 Claims, 16 Drawing Sheets



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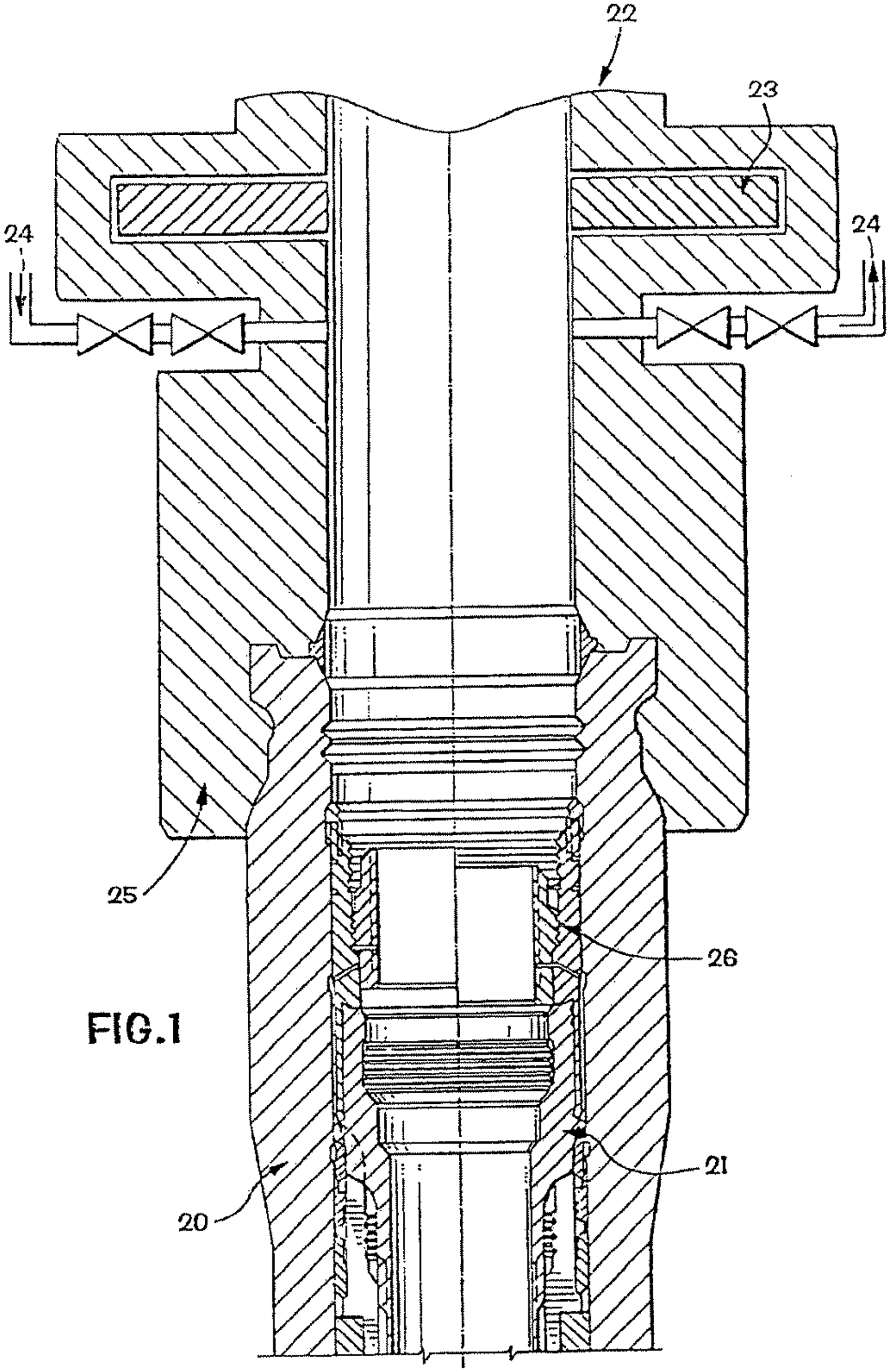


FIG.1

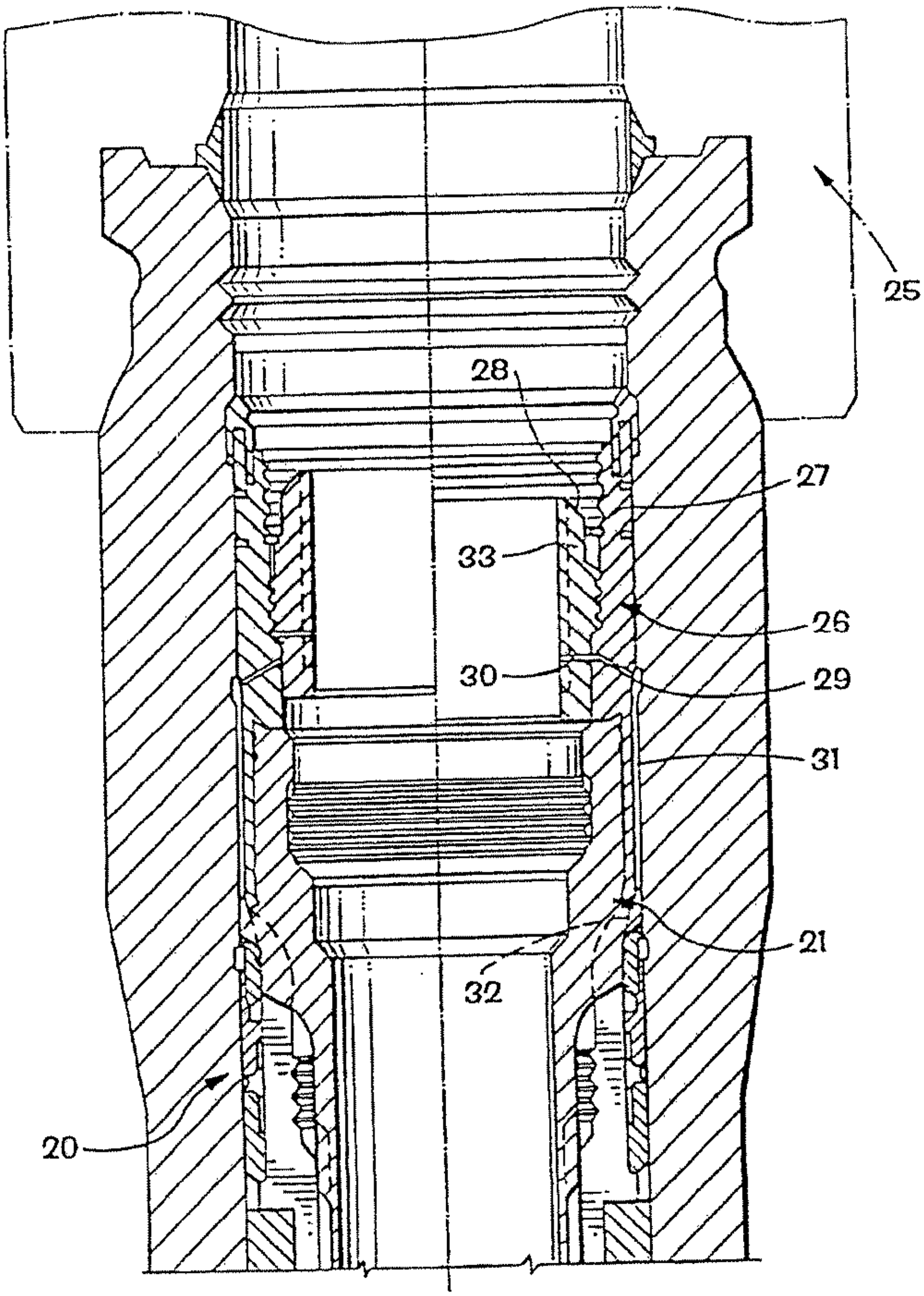
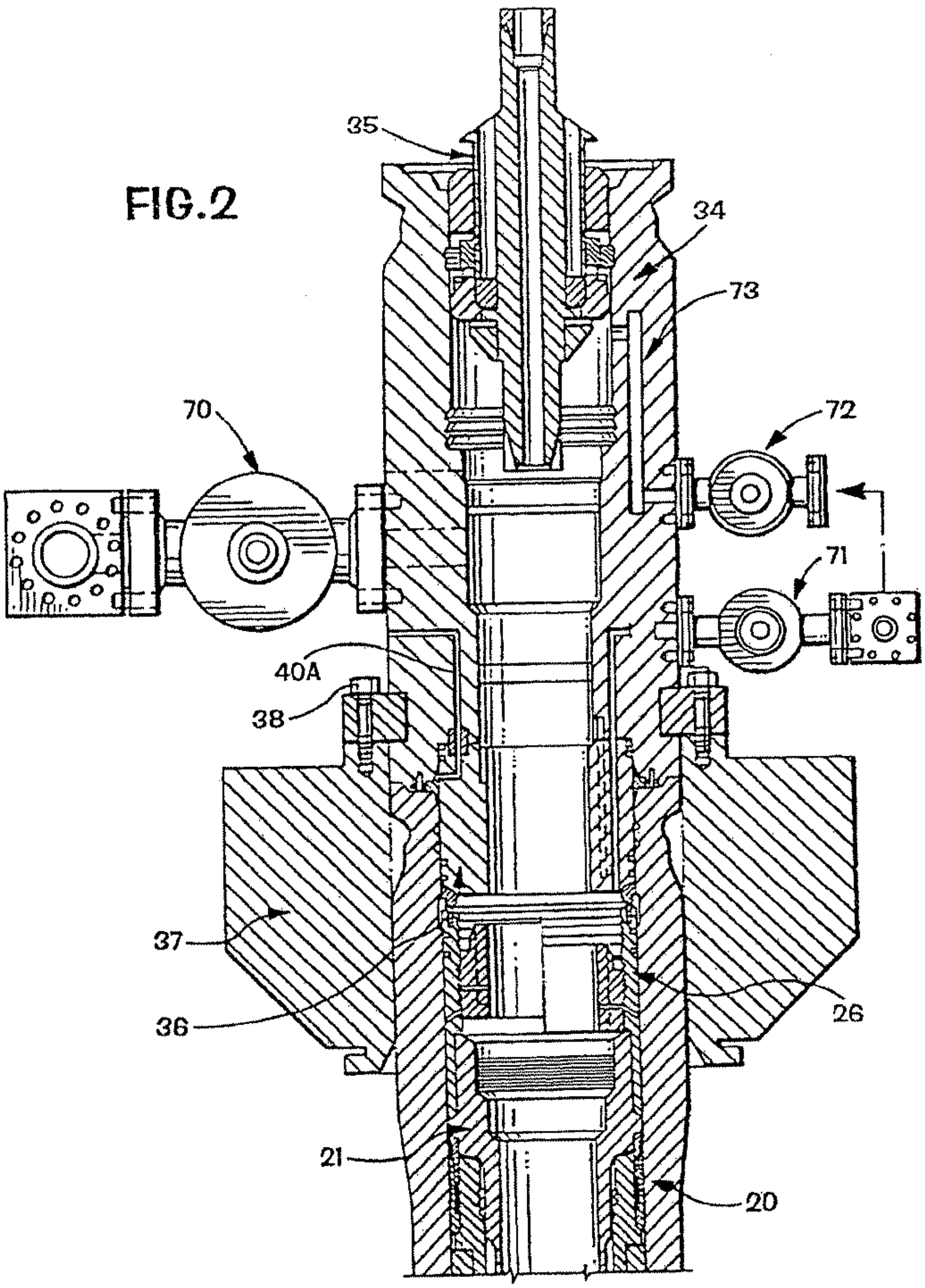


FIG.1A

FIG.2



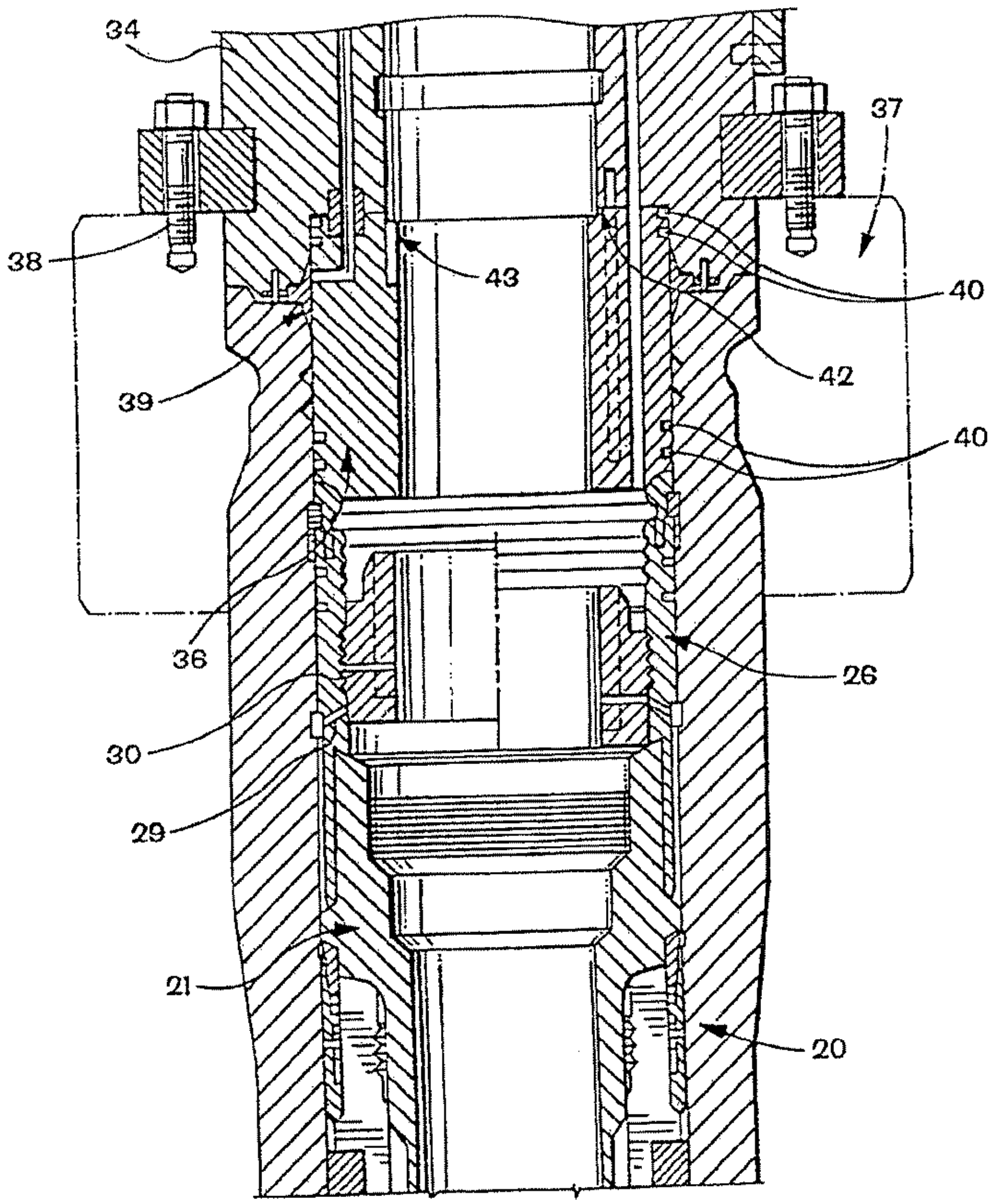


FIG.2A

FIG.3

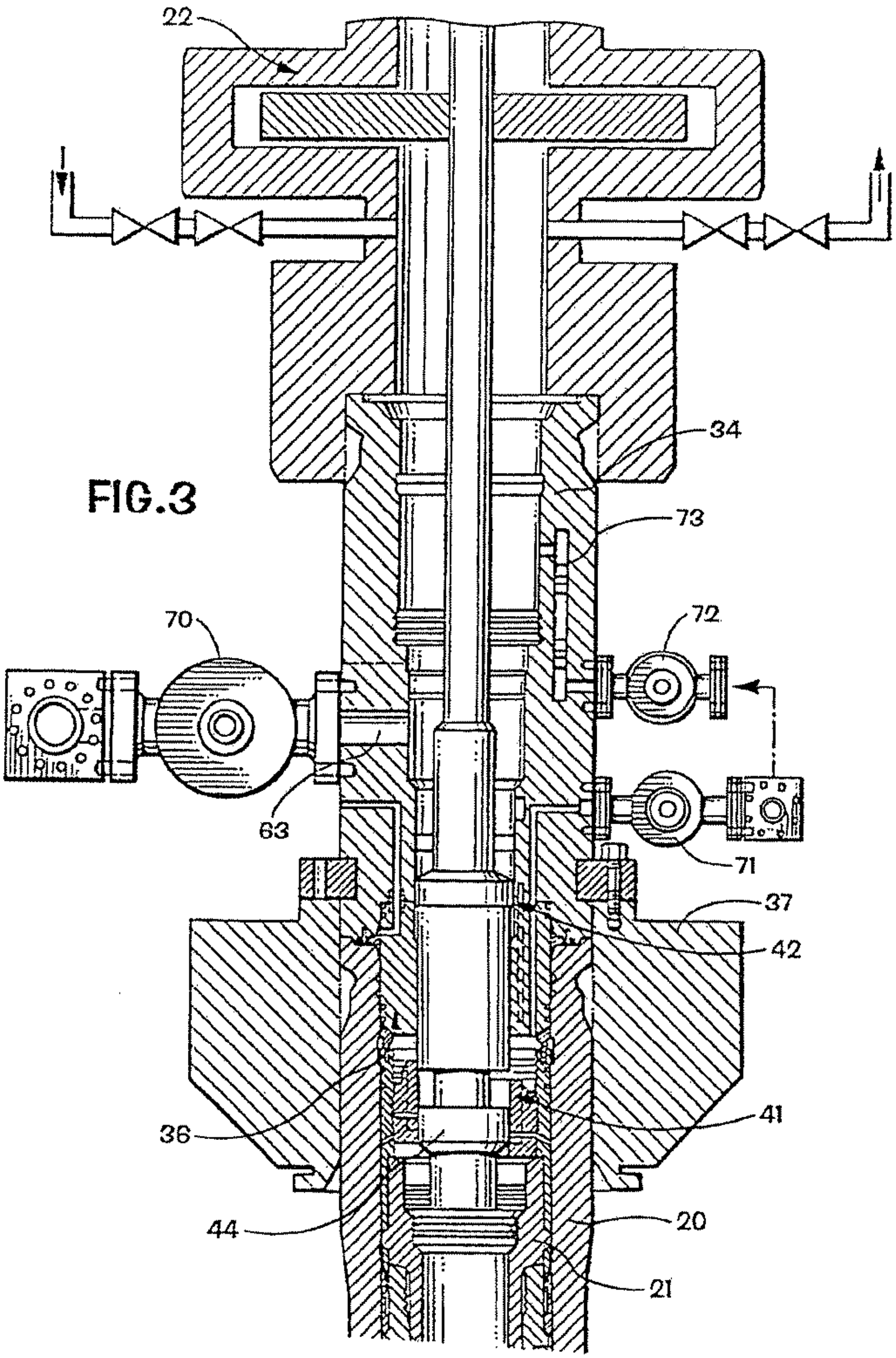
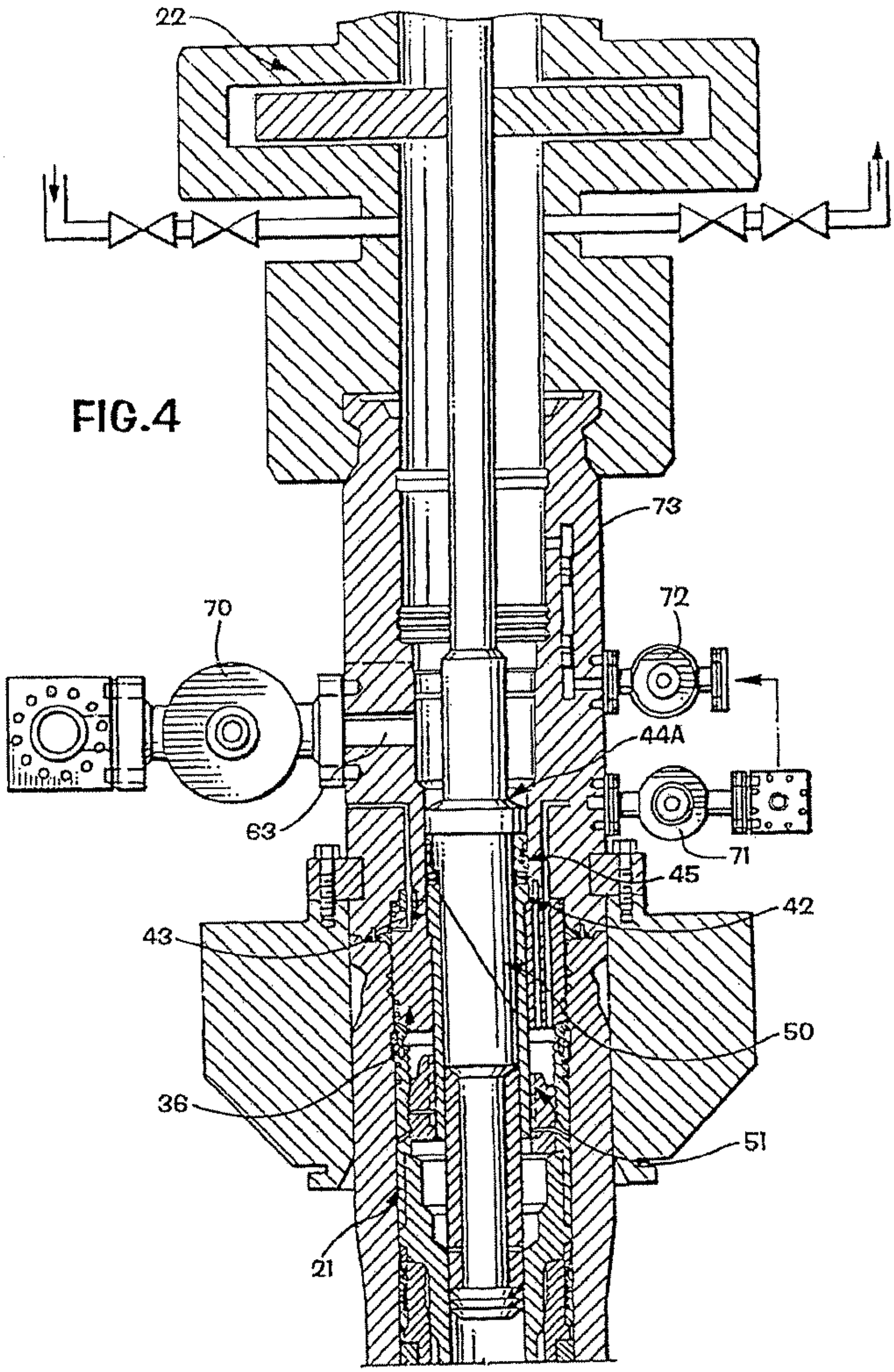


FIG.4



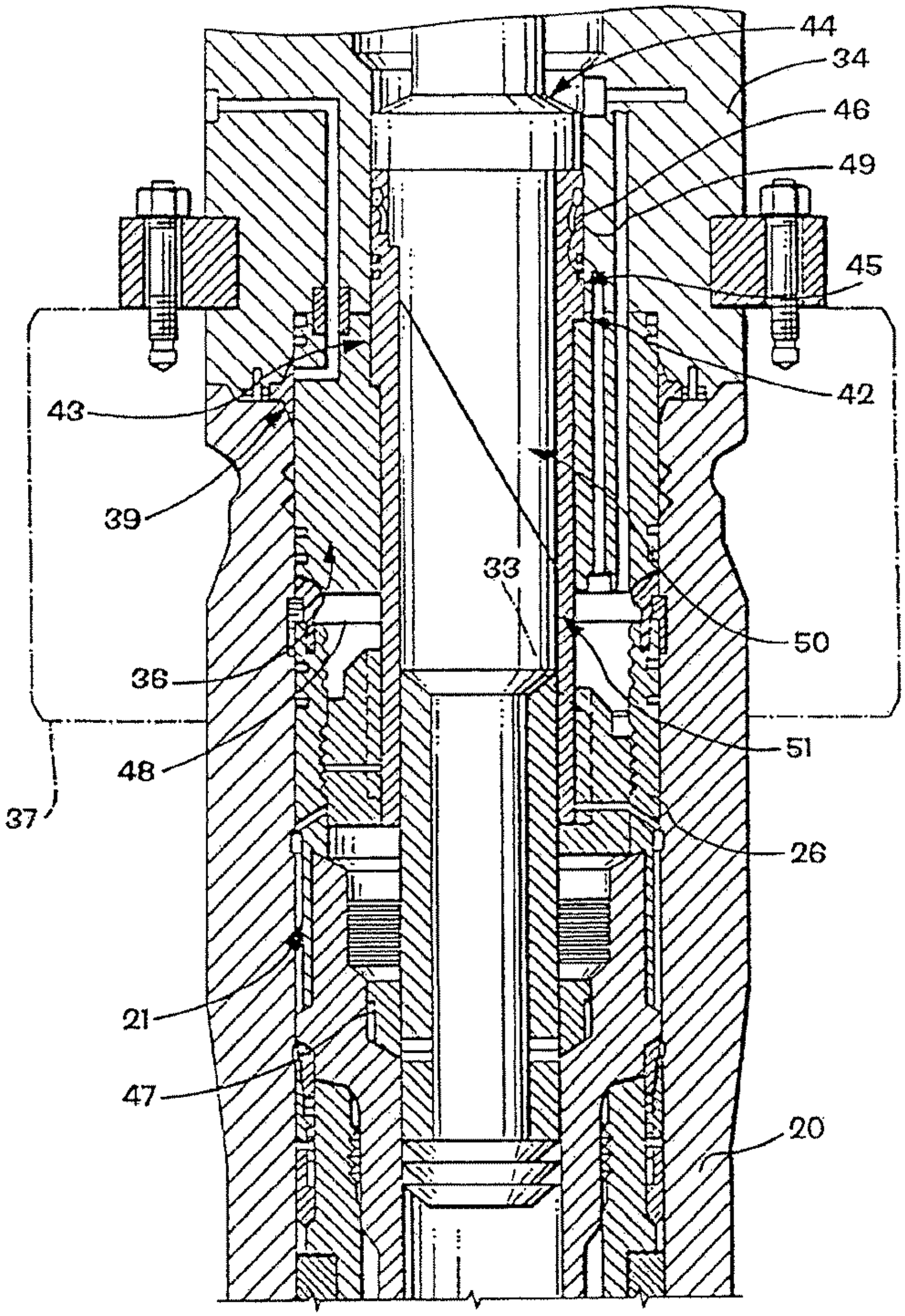


FIG.4A

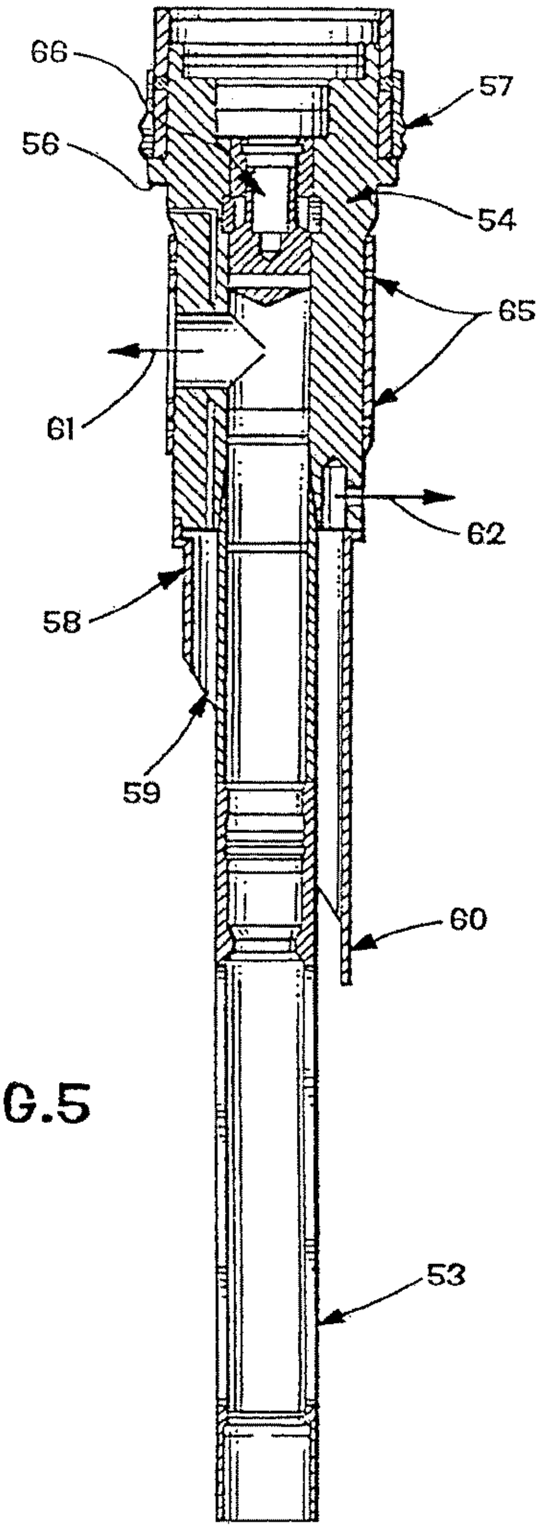


FIG.5

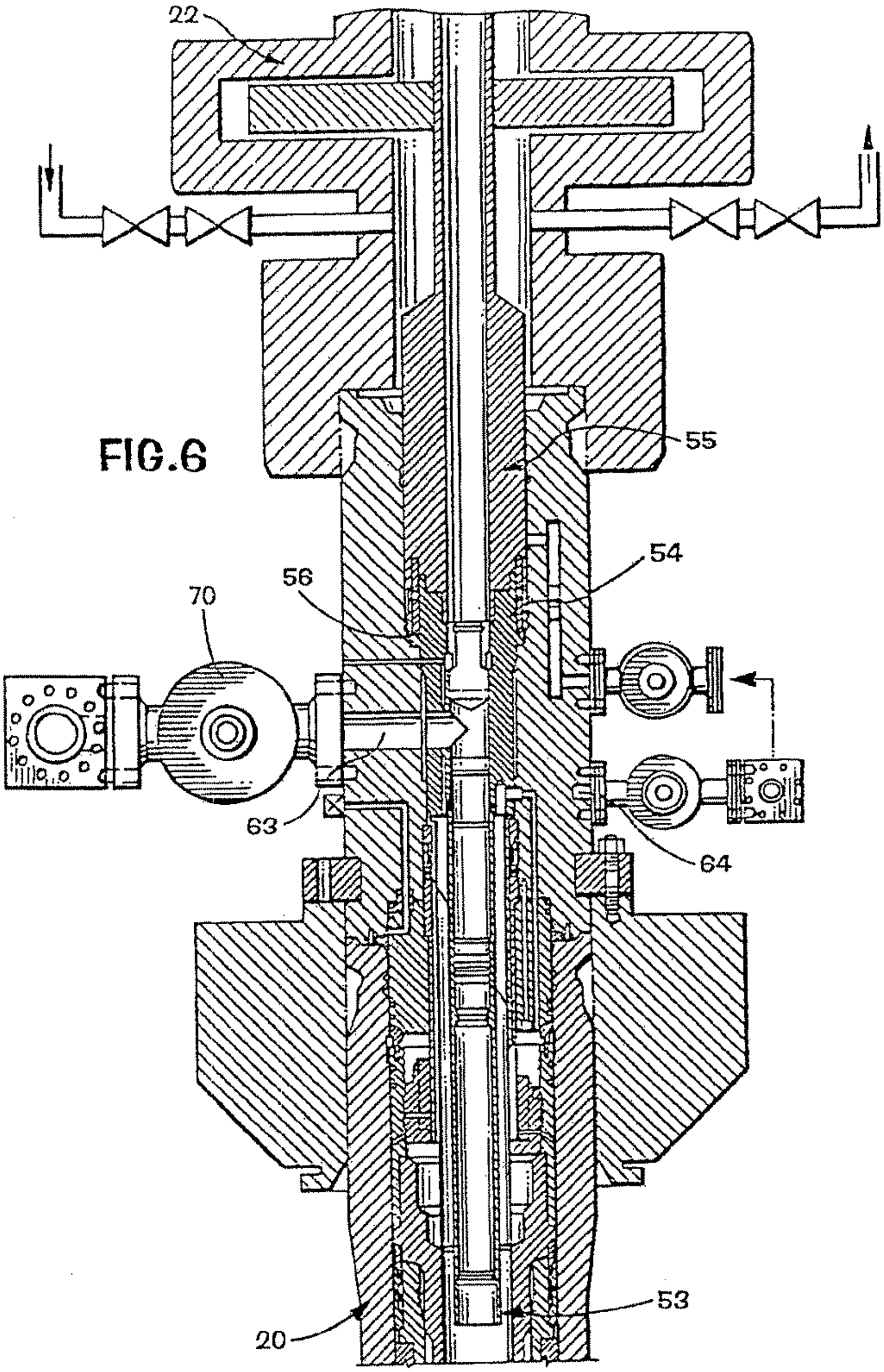
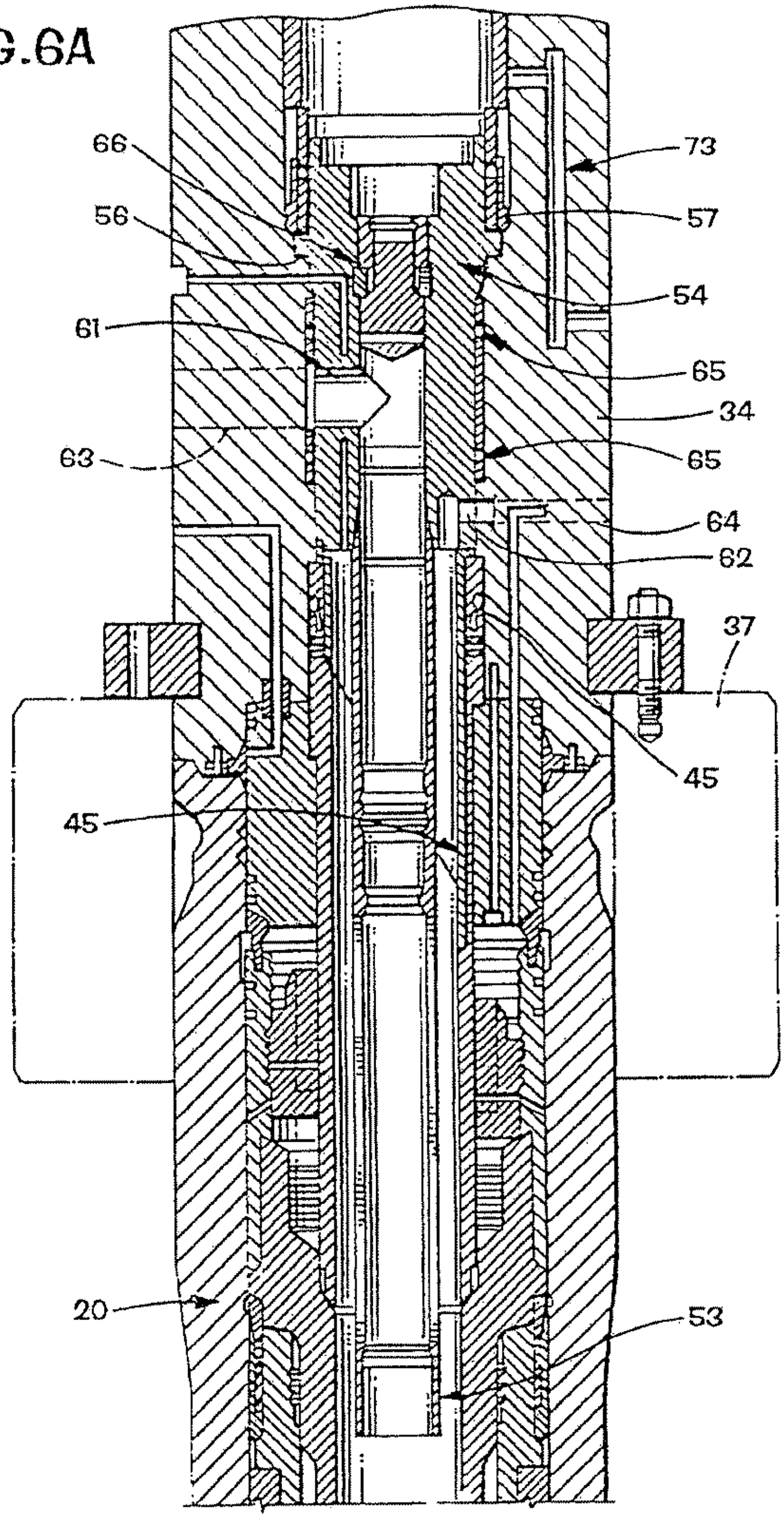


FIG.6

FIG.6A



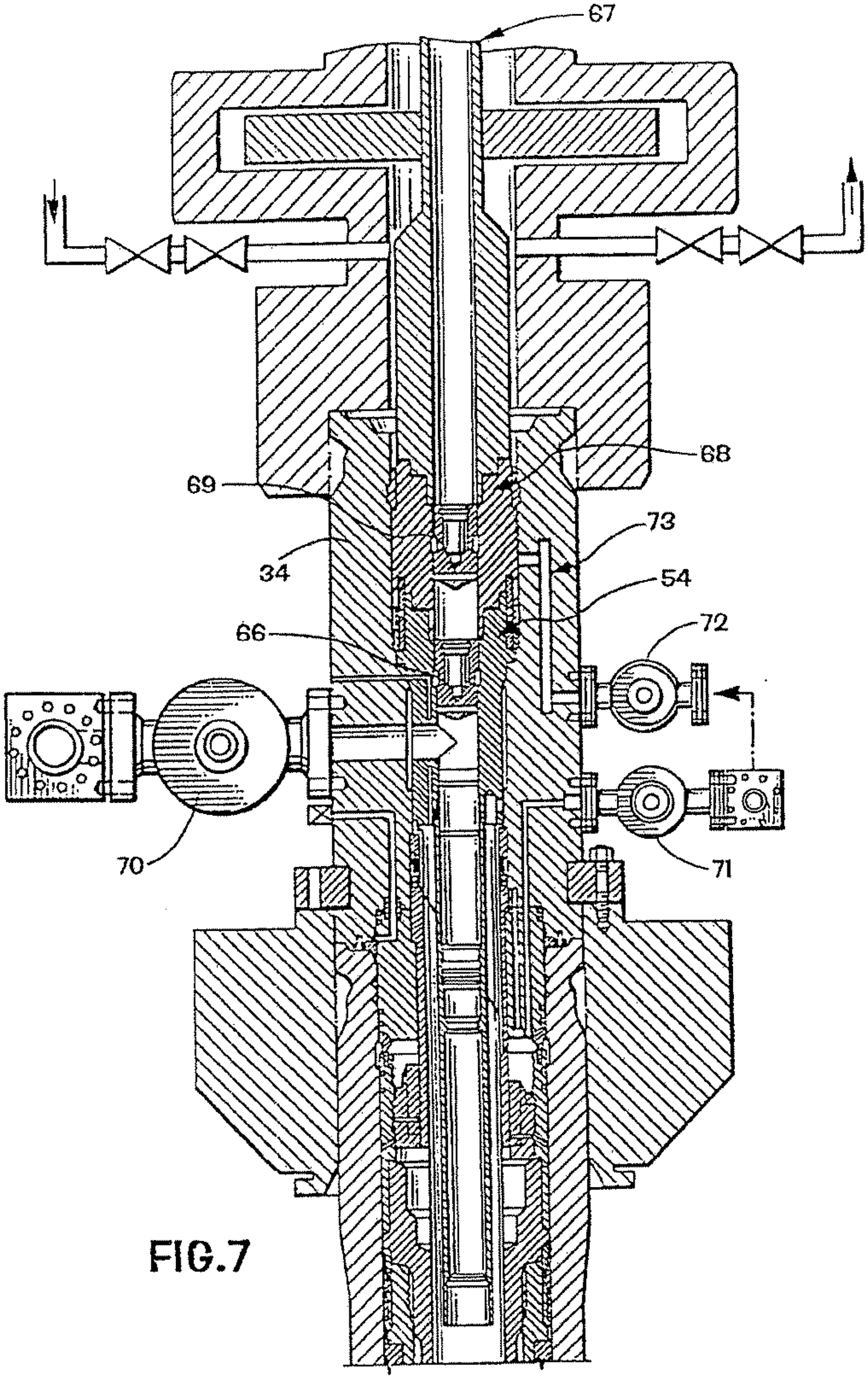


FIG.7

FIG.8

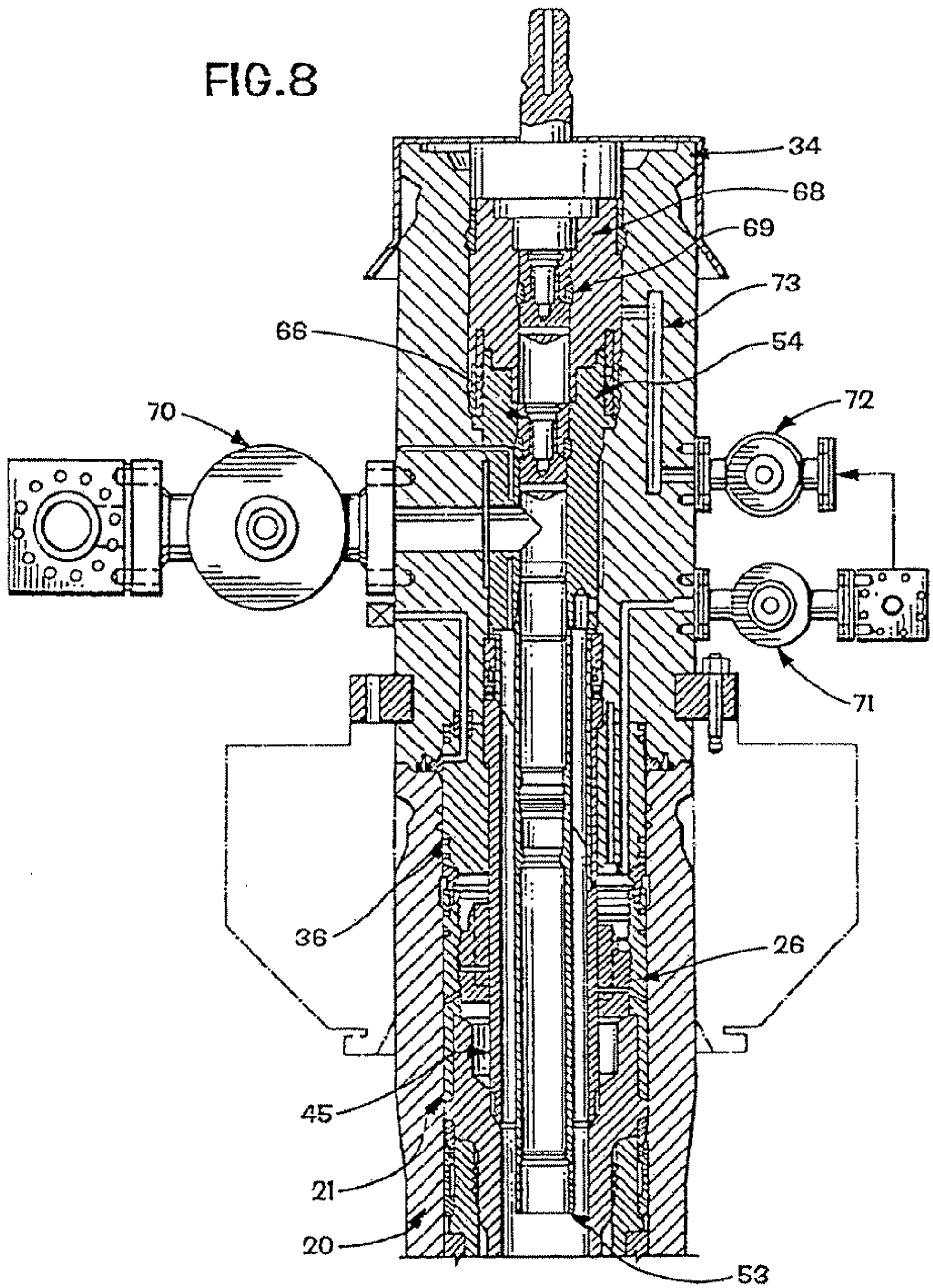


FIG.9

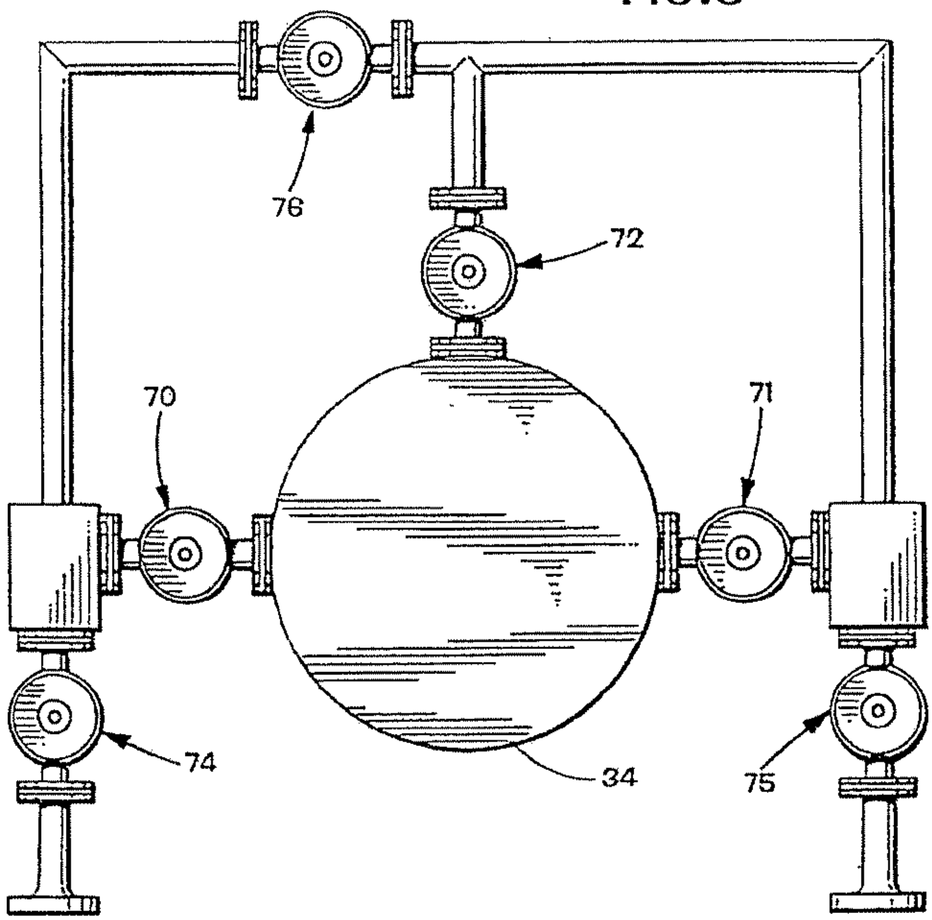


FIG.13

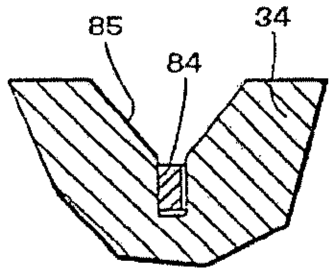


FIG.13A

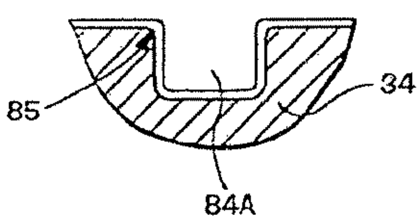


FIG.13B

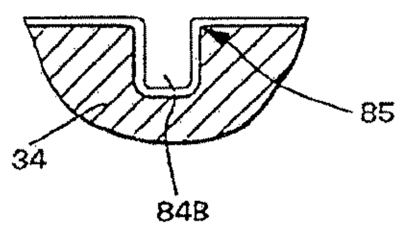
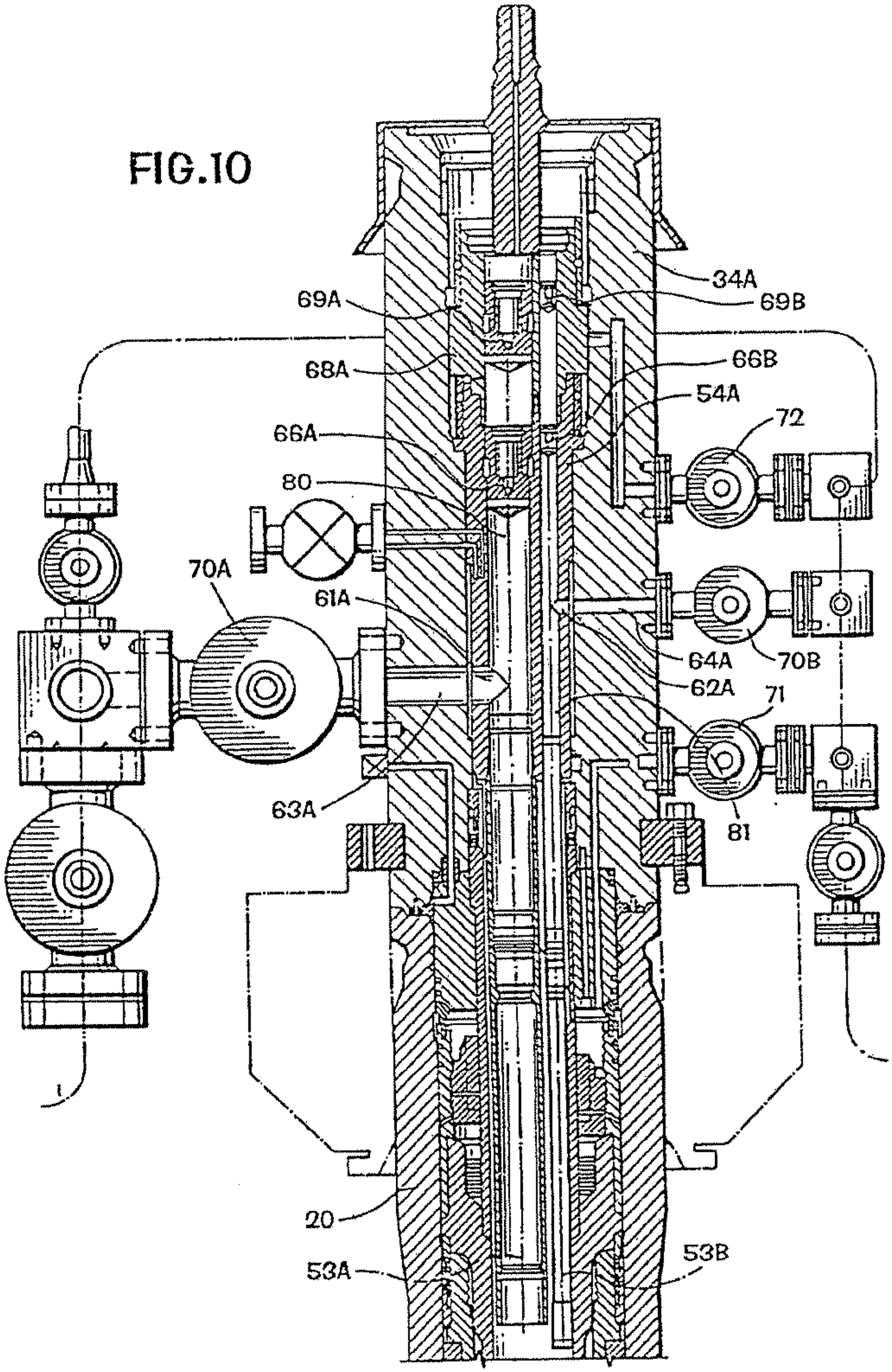


FIG.10



34A
69A
69B
68A
66B
54A
72
66A
80
70A
61A
64A
70B
62A
71
63A
81
20
53B
53A

FIG.11

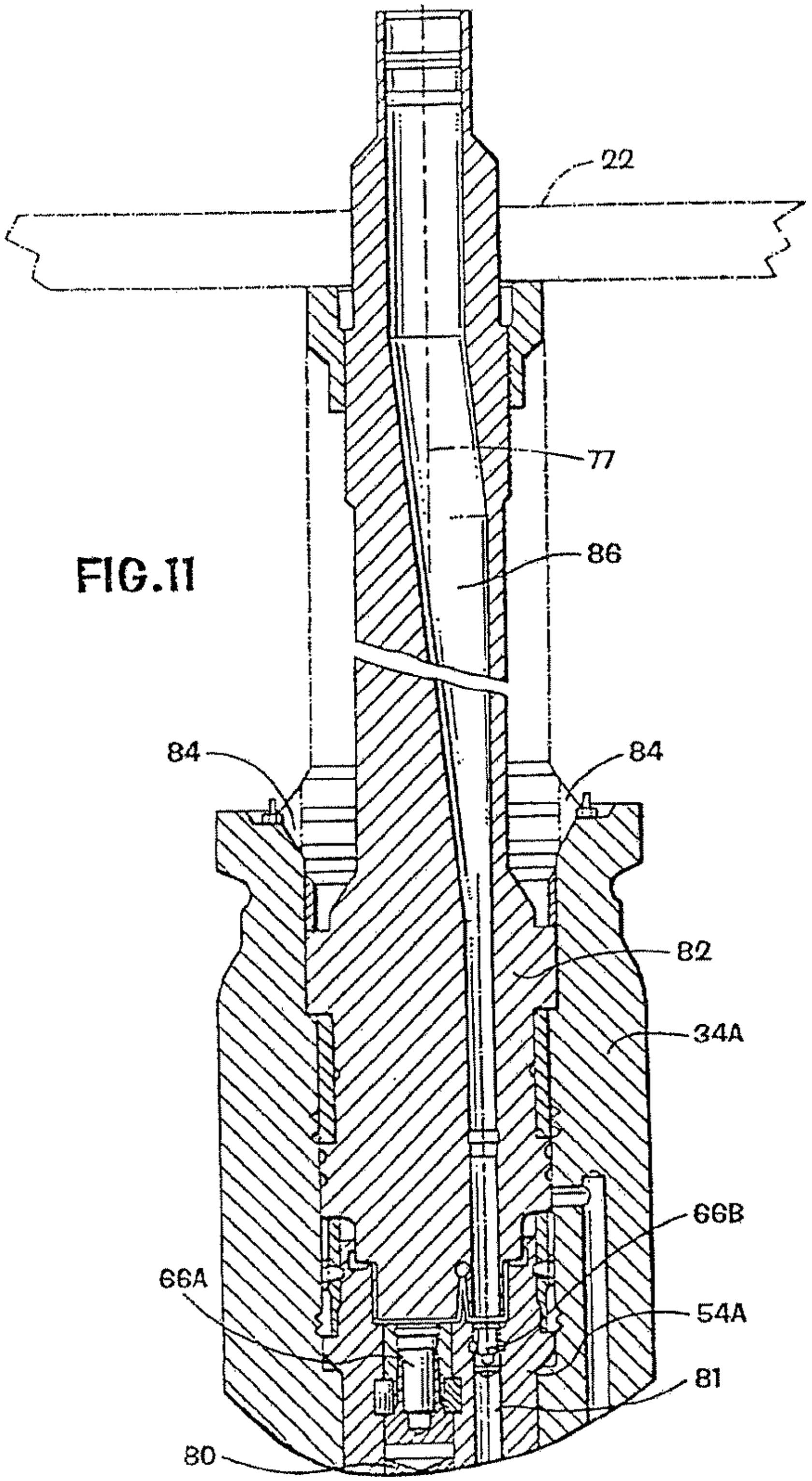
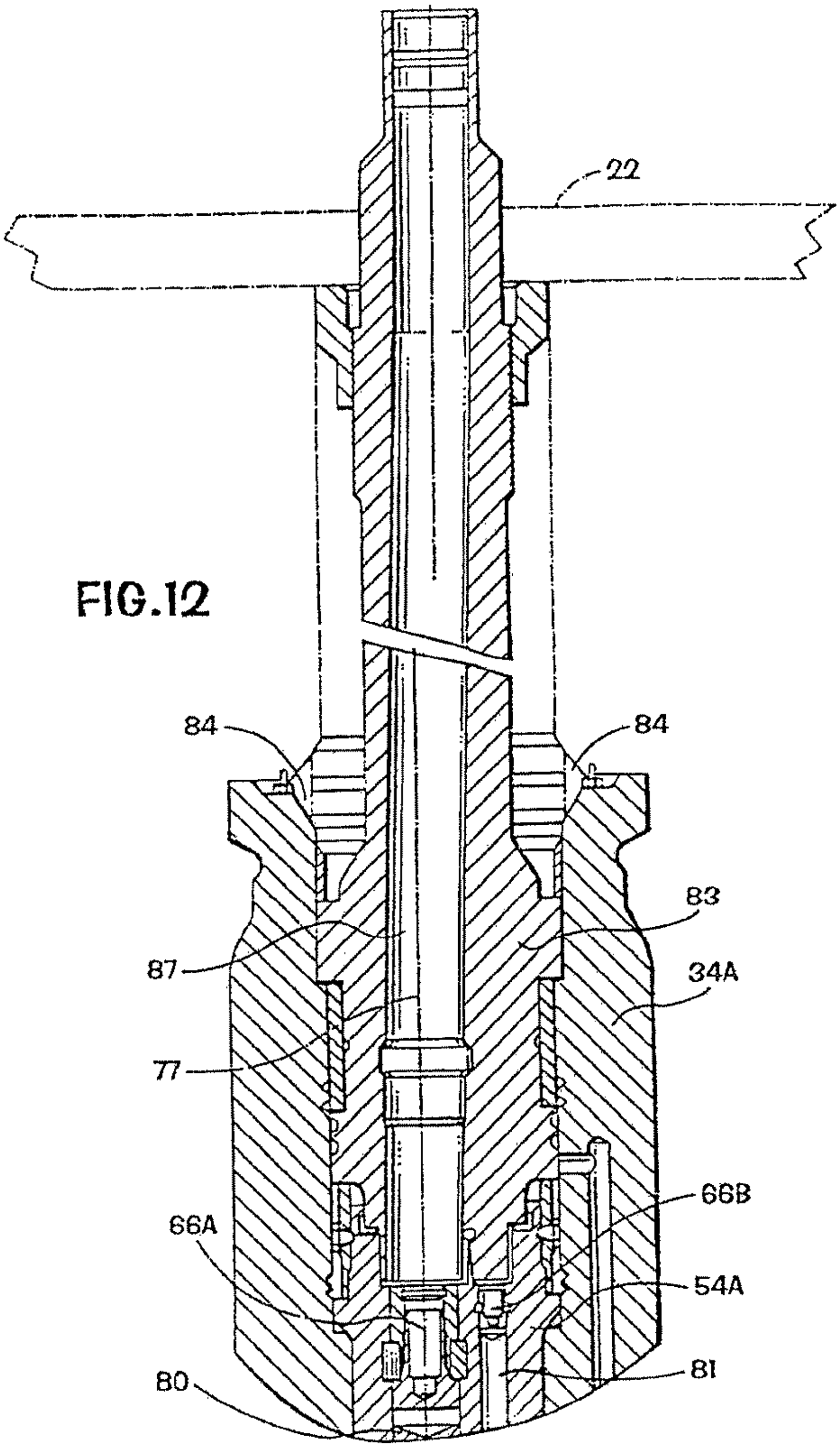


FIG.12



WELL OPERATIONS SYSTEM

RELATED APPLICATIONS

This is a continuation of application Ser. No. 09/092,549 filed Jun. 5, 1998, now abandoned, which is a divisional continuing application Ser. No. 08/679,560 filed Jul. 12, 1996, now U.S. Pat. No. 6,039,119, which is a continuation of Ser. No. 08/204,397 filed Mar. 16, 1994, now U.S. Pat. No. 5,544,707, which is a 371 of PCT application PCT/US93/05246 filed on May 28, 1993, which claims the priority of European Patent Office application 92305014 filed on Jun. 1, 1992, all of the above hereby incorporated herein by reference.

Conventionally, wells in oil and gas fields are built up by establishing a wellhead housing, and with a drilling blow out preventer stack (BOP) installed, drilling down to produce the well hole whilst successively installing concentric casing strings, which are cemented at the lower ends and sealed with mechanical seal assemblies at their upper ends. In order to convert the cased well for production, a tubing string is run in-through the BOP and a hanger at its upper end landed in the wellhead. Thereafter the drilling BOP stack is removed and replaced by a Christmas tree having one or more production bores containing actuated valves and extending vertically to respective lateral production fluid outlet ports in the wall of the Christmas tree.

This arrangement has involved problems which have, previously, been accepted as inevitable. Thus any operations down hole have been limited to tooling which can pass through the production bore, which is usually no more than five inch diameter, unless the Christmas tree is first removed and replaced by a BOP stack. However this involves setting plugs or valves, which may be unreliable by not having been used for a long time, down hole. The well is in a vulnerable condition whilst the Christmas tree and BOP stack are being exchanged and neither one is in position, which is a lengthy operation. Also, if it is necessary to pull the completion, consisting essentially of the tubing string on its hanger, the Christmas tree must first be removed and replaced by a BOP stack. This usually involves plugging and/or killing the well.

A further difficulty which exists, particularly with subsea wells, is in providing the proper angular alignment between the various functions, such as fluid flow bores, and electrical and hydraulic lines, when the wellhead equipment, including the tubing hanger, Christmas tree, BOP stack and emergency disconnect devices are stacked up. Exact alignment is necessary if clean connections are to be made without damage as the devices are lowered into engagement with one another. This problem is exacerbated in the case of subsea wells as the various devices which are to be stacked up are run down onto guide posts or a guide funnel projecting upwardly from a guide base. The post receptacles which ride down on to the guide posts or the entry guide into the funnel do so with appreciable clearance. This clearance inevitably introduces some uncertainty in alignment and the aggregate misalignment when multiple devices are stacked, can be unacceptably large. Also the exact orientation will depend upon the precise positions of the posts or keys on a particular guide base and the guides on a particular running tool or BOP stack and these will vary significantly from one to another. Consequently it is preferable to ensure that the same running tools or BOP stack are used for the same wellhead, or a new tool or stack may have to be specially modified for a particular wellhead. Further misalignments can arise from the manner in which the guide base is bolted to the conductor casing of the wellhead.

In accordance with the present invention, a wellhead comprises a wellhead housing; a spool tree fixed and sealed to the housing, and having at least a lateral production fluid outlet port connected to an actuated valve; and a tubing hanger landed within the spool tree at a predetermined angular position at which a lateral production fluid outlet port in the tubing hanger is in alignment with that in the spool tree.

With this arrangement, the spool tree, takes the place of a conventional Christmas tree but differs therefrom in having a comparatively large vertical through bore without any internal valves and at least large enough to accommodate the tubing completion. The advantages which are derived from the use of such spool tree are remarkable, in respect to safety and operational benefits.

Thus, in workover situations the completion, consisting essentially of the tubing string, can be pulled through a BOP stack, without disturbing the spool tree and hence the pressure integrity of the well, whereafter full production casing drift access is provided to the well through the large bore in the spool tree. The BOP can be any appropriate workover BOP or drilling BOP of opportunity and does not have to be one specially set up for that well.

Preferably, there are complementary guide means on the tubing hanger and spool tree to rotate the tubing hanger into the predetermined angular position relatively to the spool tree as the tubing hanger is lowered on to its landing. With this feature the spool tree can be landed at any angular orientation onto the wellhead housing and the guide means ensures that the tubing string will rotate directly to exactly the correct angular orientation relatively to the spool tree quite independently of any outside influence. The guide means to control rotation of the tubing hanger into the predetermined angular orientation relatively to the spool tree may be provided by complementary oblique edge surfaces one facing downwardly on an orientation sleeve depending from the tubing hanger the other facing upwardly on an orientation sleeve carried by the spool tree.

Whereas modern well technology provides continuous access to the tubing annulus around the tubing string, it has generally been accepted as being difficult, if not impossible, to provide continuous venting and/or monitoring of the pressure in the production casing annulus, that is the annulus around the innermost casing string. This has been because the production casing annulus must be securely sealed whist the Christmas tree is fitted in place of the drilling BOP, and the Christmas tree has only been fitted after the tubing string and hanger has been run in, necessarily inside the production casing hanger, so that the production casing hanger is no longer accessible for the opening of a passageway from the production casing annulus. However, the new arrangement, wherein the spool tree is fitted before the tubing string is run in provides adequate protected access through the BOP and spool tree to the production casing hanger for controlling a passage from the production casing annulus.

For this purpose, the wellhead may include a production casing hanger landed in the wellhead housing below the spool tree; an isolation sleeve which is sealed at its lower end to the production casing hanger and at its upper end to the spool tree to define an annular void between the isolation sleeve and the housing; and an adapter located in the annular space and providing part of a passage from the production casing annulus to a production casing annulus pressure monitoring port in the spool tree, the adapter having a valve for opening and closing the passage, and the valve being operable through the spool tree after withdrawal of the

isolation sleeve up through the spool tree. The valve may be provided by a gland nut, which can be screwed up and down within a body of the adapter to bring parts of the passage formed in the gland nut and adapter body, respectively, into and out of alignment with one another. The orientation sleeve for the tubing hanger may be provided within the isolation sleeve.

Production casing annulus pressure monitoring can then be set up by method of completing a cased well in which a production casing hanger is fixed and sealed by a seal assembly to a wellhead housing, the method comprising, with BOP installed on the housing, removing the seal assembly and replacing it with an adapter which is manipulatable between configurations in which a passages from the production casing, annulus up past the production casing hanger is open or closed; with the passage closed, removing the BOP and fitting to the housing above the production casing hanger a spool tree having an internal landing for a tubing hanger; installing a BOP on the spool tree; running a tool down through the BOP and spool tree to manipulate the valve and open the passage; inserting through the BOP and spool tree an isolation sleeve, which seals to both the production casing and spool tree and hence defines between the sleeve and casing an annular void through which the passage leads to a production casing annulus pressure monitoring port in the spool tree; and running a tubing string down through the BOP and spool tree until the tubing hanger lands in the spool tree with lateral outlet ports in the tubing hanger and spool tree for production fluid flow, in alignment with one another.

According to a further feature of the invention the spool tree has a downwardly depending location mandrel which is a close sliding fit within a bore of the wellhead housing. The close fit between the location mandrel of the spool tree and the wellhead housing provides a secure mounting which transmits inevitable bending stresses to the housing from the heavy equipment, such as a BOP, which projects upwardly from the top of the wellhead housing, without the need for excessively sturdy connections. The location mandrel may be formed as an integral part of the body of the spool tree, or may be a separate part which is securely fixed, oriented and sealed to the body.

Pressure integrity between the wellhead housing and spool tree may be provided by two seals positioned in series one forming an environmental seal (such as an AX gasket) between the spool tree and the wellhead housing, and the other forming a production seal between the location mandrel and either the wellhead housing or the production casing hanger.

During workover operations, the production casing annulus can be resealed by reversing the above steps, if necessary after setting plugs or packers down hole.

When production casing pressure monitoring is unnecessary, so that no isolation sleeve is required, the orientation sleeve carried by the spool tree for guiding and rotating the tubing hanger down into the correct angular orientation may be part of the spool tree location mandrel itself.

Double barrier isolation, that is to say two barriers in series, are generally necessary for containing pressure in a well. If a spool tree is used instead of a conventional Christmas tree, there are no valves within the vertical production and annulus fluid flow bores within the tree, and alternative provision must be made for sealing the bore or bores through the top of the spool tree which provide for wire line or drill pipe access.

In accordance with a further feature of the invention, at least one vertical production fluid bore in the tubing hanger is sealed above the respective lateral production fluid outlet port by means of a removable plug, and the bore through the spool tree being sealed above the tubing hanger by means of a second removable plug.

With this arrangement, the first plug, takes the function of a conventional swab valve, and may be a wireline set plug. The second plug could be a stopper set in the spool tree above the tubing hanger by, e.g., a drill pipe running tool. The stopper could contain at least one wireline retrievable plug which would allow well access when only wire line operations are called for. The second plug should seal and be locked internally into the spool tree as it performs a barrier to the well when a BOP or intervention module is deployed. A particular advantage of this double plug arrangement is that, as is necessary to satisfy authorities in some jurisdictions, the two independent barriers are provided in mechanically separate parts, namely the tubing hanger and its plug and the second plug in the spool tree.

A further advantage arises if a workover port extends laterally through the wall of the spool tree from between the two plugs; a tubing annulus fluid port extends laterally through the wall of the spool tree from the tubing annulus; and these two ports through the spool tree are interconnected via an external flow line containing at least one actuated valve. The bore from the tubing annulus can then terminate at the port in the spool tree and no wireline access to the tubing annulus bore is necessary through the spool tree as the tubing annulus bore can be connected via the interplug void to choke or kill lines, i.e. a BOP annulus, so that downhole circulation is still available. It is then only necessary to provide wireline access at workover situations to the production bore or bores. This considerably simplifies workover BOP and/or riser construction. When used in conjunction with the plug at the top of the spool tree, the desirable double barrier isolation is provided by the spool tree plug over the tubing hanger, or workover valve from the production flow.

When the well is completed as a multi production bore well, in which the tubing hanger has at least two vertical production through bores each with a lateral production fluid flow port aligned with the corresponding port in the spool tree, at least two respective connectors may be provided for selective connection of a single bore wire line running tool to one or other of the production bores, each connector having a key for entering a complementary formation at the top of the spool tree to locate the connector in a predetermined angular orientation relatively to the spool tree. The same type of alternative connectors may be used for providing wireline or other running tool access to a selected one of a plurality of functional connections, e.g. electrical or hydraulic couplings, at the upper end of the tubing hanger.

The development and completion of a subsea wellhead in accordance with the present invention are illustrated in the accompanying drawings, in which:

FIGS. 1 to 8 are vertical axial sections showing successive steps in development and completion of the wellhead, the Figure numbers bearing the letter A being enlargements of part of the corresponding Figures of same number without the A:

FIG. 9 is a circuit diagram showing external connections to the spool 3;

FIG. 10 is a vertical axial section through a completed dual production bore well in production mode;

FIGS. 11 and 12 are vertical axial sections showing alternative connectors to the upper end of the dual production bore wellhead during work over; and,

FIG. 13 is a detail showing the seating of one of the connectors in the spool tree.

FIG. 1 shows the upper end of a cased well having a wellhead housing 20, in which casing hangers, including an uppermost production casing hanger 21 for, for example, 9⅝" or 10¾", production casing is mounted in conventional manner. FIG. 1 shows a conventional drilling BOP 22 having rams 23 and kill and choke lines 24 connected to the upper end of the housing 20 by a drilling connector 25.

As seen in more detail in FIG. 1A, the usual mechanical seal assemblies between the production casing hanger 21 and the surrounding wellhead housing 20 have been removed and replaced through the BOP with an adapter 26 consisting of an outer annular body part 27 and an inner annular gland nut 28 which has a screw threaded connection to the body 27 so that it can be screwed between a lowered position shown on the right hand side of FIG. 1A, in which radial ducts 29 and 30, respectively in the body 27 and nut 28, are in communication with one another, and a raised position shown on the left hand side of FIG. 1A, in which the ducts are out of communication with one another. The duct 29 communicates through a conduit 31 between a depending portion of the body 27 and the housing 20, and through a conduit 32 passing through the production casing hanger 21, to the annulus surround the production casing. The duct 30 communicates through channels 33 formed in the radially inner surface of the nut 28, and hence to a void to be described. The cooperation between the gland nut 28 and body 27 of the adapter therefore acts as a valve which can open and close a passage up past the production casing hanger from the production casing annulus. After appropriate testing, a tool is run in through the BOP and, by means by radially projecting spring lugs engaging in the channels 33, rotates the gland nut 28 to the valve closed position shown on the right hand side on FIG. 1A. The well is thus resealed and the drilling BOP 22 can temporarily be removed.

As shown in FIGS. 2 and 2A, the body of a tree spool 34 is then lowered on a tree installation tool 35, using conventional guide post location, or a guide funnel in case of deep water, until a spool tree mandrel 36 is guided into alignment with and slides as a close machined fit, into the upper end of the wellhead housing 20, to which the spool tree is then fixed via a production connector 37 and bolts 48. The mandrel 36 is actually a separate part which is bolted and sealed to the rest of the spool tree body. As seen particularly in FIG. 2A a weight set AX gasket 39, forming a metal to metal environmental seal is provided between the spool tree body and the wellhead housing 20. In addition two sets of sealing rings 40 provide, in series with the environmental seal, a production fluid seal externally between the ends to the spool tree mandrel 36 to the spool tree body and to the wellhead housing 20. The intervening cavity can be tested through a test part 40A. The provision of the adapter 26 is actually optional, and in its absence the lower end of the spool tree mandrel 36 may form a production seal directly with the production casing hanger 21. As is also apparent from reasons which will subsequently become apparent, the upper radially inner edge of the spool tree mandrel projects radially inwardly from the inner surface of the spool tree body above, to form a landing shoulder 42 and at least one machined key slot 43 is formed down through the landing shoulder.

As shown in FIG. 3, the drilling BOP 22 is reinstalled on the spool tree 34. The tool 44 used to set the adapter in FIG. 1, having the spring dogs 45, is again run in until it lands on the shoulder 42, and the spring dogs 45 engage in the channels 33. The tool is then turned to screw the gland nut 28 down within he body 27 of the adapter 26 to the valve open position shown on the right hand side in FIG. 1A. It is now safe to open the production casing annulus as the well is protected by the BOP.

The next stage, show in FIGS. 4 and 4A, is to run in through the BOP and spool tree on an appropriate tool 44A a combined isolation and orientation sleeve 45. This lands on the shoulder 42 at the top of the spool tree mandrel and is rotated until a key on the sleeve drops into the mandrel key slot 43. This ensures precise angular orientation between the sleeve 45 and the spool tree 44, which is necessary, and in contrast to the angular orientation between the spool tree 34 and the wellhead casing, which is arbitrary. The sleeve 45 consists of an external cylindrical portion, an upper external surface of which is sealed by ring seals 46 to the spool tree 34, and the lower external surface of which is sealed by an annular seal 47 to the production casing hanger 21. There is thus provided between the sleeve 45 and the surrounding wellhead casing 20 a void 48 with which the channels 33, now defined radially inwardly by the sleeve 45, communicate. The void 48 in turn communicates via a duct 49 through the mandrel and body of the spool tree 34 to a lateral port. It is thus possible to monitor and vent the pressure in the production casing annulus through the passage provided past the production casing hanger via the conduits 32, 31 the ducts 29 and 30, the channels 33, shown in FIG. 1A, the void 48, the duct 49, and the lateral port in the spool tree. In the drawings, the radial portion of the duct 49 is shown apparently communicating with a tubing annulus, but this is draughtsman's licence and the ports from the two annuli are, in fact, angularly and radially spaced.

Within the cylindrical portion of the sleeve 45 is a lining, which may be fixed in the cylindrical portion, or left after internal machining of the sleeve. This lining provides an orientation sleeve having an upper/edge forming a cam 50. The lowermost portion of the cam leads into a key slot 51.

As shown in FIGS. 5, 6 and 6A a tubing string of production tubing 53 on a tubing hanger 54 is run in through the BOP 22 and spool tree 34 on a tool 55 until the tubing hanger lands by means of a keyed shoulder 56 on a landing in the spool tree and is locked down by a conventional mechanism 57. The tubing hanger 54 has a depending orientation sleeve 58 having an oblique lower edge forming a cam 59 which is complementary to the cam 50 in the sleeve 45 and, at the lower end of the cam, a downwardly projecting key 60 which is complementary to the key slot 51. The effect of the cams 50 and 59 is that, irrespective of the angular orientation of the tubing string as it is run in, the cams will cause the tubing hanger 54 to be rotated to its correct angular orientation relatively to the spool tree and the engagement of the key 60 in the key slot 51 will lock this relative orientation between the tubing hanger and spool tree, so that lateral production and tubing annulus fluid flow ports 61 and 62 in the tubing hanger 54 are in alignment with respective lateral production and tubing annulus fluid flow ports 63 and 64 through the wall of the spool tree. Metal to metal annulus seals 65, which are set by the weight of the tubing string, provide production fluid seals between the tubing hanger 54 and the spool tree 34. Provision is made in the top of the tubing hanger 54 for a wireline set plug 66. The keyed shoulder 56 of the tubing hanger lands in a complementary machined step in the spool tree 34 to ensure ultimate machined accuracy, of orientation between the tubing hanger 54 and the spool tree 34.

FIG. 7 shows the final step in the completion of the spool tree. This involves the running down on drill pipe 67 through

the BOP, an internal isolation stopper 68 which seals within the top of the spool tree 34 and has an opening closed by an in situ wireline activated plug 69. The BOP can then be removed leaving the wellhead in production mode with double barrier isolation at the upper end of the spool tree provided by the plugs 66 and 69 and the stopper 68. The production fluid outlet is controlled by a master control valve 70 and pressure through the tubing annulus outlet ports 62 and 64 is controlled by an annulus master valve 71. The other side of this valve is connected, through a workover valve 72 to a lateral workover port 73 which extends through the wall of the spool tree to the void between the plugs 69 and 66. With this arrangement, wireline access to the tubing annulus in and downstream of a tubing hanger is unnecessary as any circulation of fluids can take place through the valves 71 and 72, the ports 62, 64 and 73, and the kill or choke lines of any BOP which has been installed. The spool tree in the completed production mode is shown in FIG. 8.

FIG. 9 shows valve circuitry associated with the completion and, in addition to the earlier views, shows a production fluid isolation valve 74, a tubing annulus valve 75 and a cross over valve 76. With this arrangement a wide variety of circulation can be achieved down hole using the production bore and tubing annulus, in conjunction with choke and kill lines extending from the BOP and through the usual riser string. All the valves are fail/safe closed if not actuated.

The arrangement shown in FIGS. 1 to 9 is a mono production bore wellhead which can be accessed by a single wireline or drill pipe, and the external loop from the tubing annulus port to the void between the two plugs at the top of the spool tree avoids the need for wireline access to the tubing annulus bore.

FIG. 10 corresponds to FIG. 8 but shows a 5½ inch×2⅜ inch dual production bore wellhead with primary and secondary production tubing 53A and 53B. Development and completion are carried out as with the monobore wellhead except that the spool tree 34A and tubing hanger 54A are elongated to accommodate lateral outlet ports 61A,63A for the primary production fluid flow from a primary bore 80 in the tubing hanger to a primary production master valve 70A, and lateral outlet ports 62A,64A for the secondary production fluid flow from a secondary bore 81 in the tubing hanger to a secondary production master valve 70B. The upper ends of the bores 80 and 81 are closed by wireline plugs 66A and 66B. A stopper 68A, which closes the upper end of the spool tree 34A has openings, in alignment with the plugs 66A and 66B, closed by wireline plugs 69A and 69B.

FIGS. 11 and 12 show how a wireline 77 can be applied through a single drill pipe to activate selectively one or other of the two wireline plugs 66A and 66B in the production bores 80 and 81 respectively. This involves the use of a selected one of two connectors 82 and 83. In practice, a drilling BOP 22 is installed and the stopper 68A is removed. Thereafter the connector 82 or 83 is run in on the drill pipe or tubing until it lands in, and is secured and sealed to the spool tree 34A. FIG. 13 shows how the correct angular orientation between the connector 82 or 83 and the spool tree 34A, is achieved by wing keys 84, which are guided by Y-shaped slots 85 in the upper inner edge of the spool tree, first to bring the connectors into the right angular orientation, and then to allow the relative axial movement between the parts to enable the stabbing function when the wireline connector engages with its respective pockets above plug 66A or 66B. To ensure equal landing forces and concentricity on initial contact, two keys 84A and 84B are recommended. As the running tool is slowly rotated under a new control weight, it is essential that the tool only enters in one fixed orientation. To ensure this key 84A is wider than key 84B and its respective Y-shaped slots. It will be seen that one of the connectors 82 has a guide duct 86 which leads the wireline to the plug 66B whereas the other connector 83 has a similar guide duct 87 which leads the wireline to the other plug 66A.

What is claimed is:

1. An apparatus for controlling fluid flow in a subsea well having a subsea wellhead supporting an outer casing at the subsea floor, comprising:

a casing hanger suspended by the subsea wellhead at the subsea floor, said casing hanger being unsealed with the wellhead;

an inner casing having a bore and suspended within the subsea wellhead by said casing hanger, said inner casing forming a casing annulus with the outer casing;

a mandrel connected to the wellhead and having an aperture forming a mandrel wall and a production port adapted for fluid communication with a tubing hanger, said casing hanger being disposed below said mandrel;

a member extending from said mandrel into the wellhead;

a casing annulus port extending through said mandrel wall to said aperture;

said member being sealed with said mandrel and said casing hanger to form a fluid passageway extending between said casing annulus and said casing annulus port;

a casing annulus valve disposed on said mandrel for controlling flow through said casing annulus port; and

fluid communication between said casing annulus and said casing annulus port via said fluid passageway.

2. The apparatus of claim 1 wherein a space is created above said casing hanger between said wellhead, casing hanger and mandrel.

3. The apparatus of claim 2 wherein a portion of said fluid passageway is formed between said space and said casing annulus.

4. An apparatus for controlling fluid flow in a well having an outer casing, comprising:

a wellhead suspending a casing hanger;

inner casing having a flow bore and suspended within said wellhead by said casing hanger, said inner casing forming a casing annulus with the outer casing;

a mandrel connected to said wellhead and having a mandrel bore forming a mandrel wall;

a fluid passageway between said mandrel bore and said casing annulus;

an annulus port extending through said mandrel wall to said mandrel bore adjacent said casing hanger;

an annulus valve disposed on said mandrel for controlling flow through said annulus port;

fluid communication between said casing annulus and said annulus port via said fluid passageway; and

a casing valve disposed on said casing hanger controlling fluid flow between said casing annulus and said mandrel bore.

5. An apparatus for controlling fluid flow in a well having an outer casing, comprising:

a wellhead suspending a casing hanger;

inner casing having a flow bore and suspended within said wellhead by said casing hanger, said inner casing forming a casing annulus with the outer casing;

a mandrel connected to said wellhead and having a mandrel bore forming a mandrel wall;

a fluid passageway between said mandrel bore and said casing annulus;

an annulus port extending through said mandrel wall to said mandrel bore adjacent said casing hanger;

an annulus valve disposed on said mandrel for controlling flow through said annulus port;

fluid communication between said casing annulus and said annulus port via said fluid passageway;

a space being created between said wellhead, casing hanger and mandrel;

a portion of the fluid passageway being formed between said space and said casing annulus; and

a casing valve for opening and closing said fluid passageway.

6. The apparatus of claim 5 wherein said casing valve includes an adapter mounted on said casing hanger and a reciprocable member movably mounted on said adapter, said member and adapter each having an annulus passageway with said member having an open position where said annulus passageways are in fluid communication and a closed position when said annulus passageways are not in fluid communication.

7. A wellhead system comprising:

a wellhead;

an inner casing suspended within said wellhead and forming a casing annulus with an outer casing;

a mandrel disposed on said wellhead and having a bore therethrough;

tubing insertable through said bore and suspended within said mandrel and said inner casing, said tubing having a flowbore and forming a tubing annulus with said inner casing;

a first valve on said mandrel for controlling flow through said tubing flowbore;

a second valve on said mandrel for controlling flow through said casing annulus;

a flow passageway from said casing annulus to said bore; and

a valve member disposed in said flow passageway for controlling flow through said casing annulus.

8. An apparatus for controlling the flow of fluids between the surface and a subsea well suspending a casing at the subsea floor, comprising:

a subsea wellhead adapted for suspending the casing at the subsea floor;

a subsea production member removably disposed on said subsea wellhead by a subsea connector and having a bore forming a wall of said subsea production member, said wall having a lateral production port and at least one lateral access port therethrough, said lateral access port communicating with the surface;

a tubing hanger with tubing and supported within said bore of said production member, said tubing hanger having a production aperture forming a tubing hanger wall and at least one access aperture extending through said wall, said access aperture not extending above said lateral production port;

said tubing having a flowbore and forming an annulus with the casing;

said production aperture providing fluid communication between said flowbore and said lateral production port; and

said access aperture providing flow communication between said annulus, said lateral access port, and the surface.

9. The apparatus of claim 8 further including a connection on the outside of the wall of the production member for controlling access from the surface to the tubing annulus.

10. A method of conducting well operations between the surface and a subsea well at the sea floor, comprising:

installing a subsea wellhead at the sea floor;

lowering a casing hanger connected to the upper end of casing through the subsea wellhead;

supporting the casing hanger and casing within the subsea wellhead;

connecting a subsea production member on the subsea wellhead using a subsea connector with the production member having a lateral production port and a lateral access bore;

communicating the lateral access bore with the surface;

aligning a production passageway and an access aperture in a tubing hanger with the lateral production port and lateral access bore, respectively, as the tubing hanger is installed in the subsea production member, the access aperture not extending above the lateral production port;

suspending tubing on the tubing hanger supported within the subsea production member and forming a tubing annulus with the casing; and

forming an access passageway from the tubing annulus to and through the access aperture in the tubing hanger and then through the lateral access bore in the production member to the surface.

11. The method of claim 10 further including a member engaging the production member and casing hanger and extending between the production member and casing hanger to form an casing annulus passageway.

12. A method for the workover of a well, comprising:

(a) disposing on a wellhead a production member with a central bore;

(b) attaching a blowout prevention member having a BOP bore above the production member;

(c) lowering tubing on a tubing hanger through the BOP bore of the blowout prevention member and into the central bore of the production member;

(d) supporting the tubing hanger within the production member;

(e) forming a flow passageway between the BOP bore and a portion of the central bore;

(f) forming a flowbore through the tubing and an annulus around the tubing;

(g) forming a production passageway from the flowbore, through a lateral port in the tubing hanger and through the wall of the production member;

(h) closing the bore of the tubing hanger above the lateral port;

(i) forming an annulus passageway from the annulus through the wall of the production member to the portion of the central bore;

(j) producing the well through the production passageway;

(k) circulating fluids through the annulus passageway;

(l) working over the well; and

repeating steps (h) through (j) above.

13. An apparatus for controlling fluid flow in a subsea well having a subsea wellhead supporting an outer casing at the subsea floor, comprising:

a casing hanger suspended by the subsea wellhead at the subsea floor, said casing hanger being unsealed with the wellhead;

an inner casing having a bore and suspended within the subsea wellhead by said casing hanger, said inner casing forming a casing annulus with the outer casing;

a mandrel connected to the wellhead and having an aperture forming a mandrel wall and a production port adapted for fluid communication with a tubing hanger;

a casing annulus port extending through said mandrel wall to said aperture;

said mandrel sealed with said casing hanger to form a fluid passageway extending between said casing annulus and said casing annulus port;

a casing annulus valve disposed on said mandrel for controlling flow through said casing annulus port;

fluid communication between said casing annulus and said casing annulus port via said fluid passageway; and

a member extending between said mandrel and casing hanger forming said fluid passageway.

14. The apparatus of claim **13** wherein said member seals with said mandrel and said casing hanger to seal off said casing annulus port.

15. A method of conducting well operations in a subsea well through a subsea wellhead supporting a casing hanger with casing, comprising:

connecting a subsea production member on the subsea wellhead with the production member having a production port and an access bore;

aligning a production passageway and an access aperture in a tubing hanger with the production port and access bore, respectively, as the tubing hanger is installed in the subsea production member;

suspending tubing on the tubing hanger supported within the subsea production member and forming a tubing annulus with the casing;

forming an access passageway from the tubing annulus to and through the access aperture in the tubing hanger and then through the access bore in the production member; and

sealing a member with the production member and casing hanger to seal off the access passageway.

16. The method of claim **15** further including removing the tubing hanger and tubing and the member providing a pressure barrier for the access passageway.

17. An apparatus for controlling fluid flow between the surface and a subsea well having a subsea wellhead supporting a casing string at the subsea floor, comprising:

a first hanger suspended by the subsea wellhead at the subsea floor, said first hanger supporting a first pipe string within the well;

a mandrel removably connected to the subsea wellhead and having an aperture forming a mandrel wall and first and second lateral ports disposed in said wall;

a second hanger landed in said mandrel having first and second apertures in fluid communication with said first and second lateral ports, respectively, said second hanger supporting a second pipe string within the subsea well and having a flow bore communicating with said first aperture and first lateral port, said first and second pipe strings forming an annulus, said second aperture not extending above said first lateral port;

said second aperture and second lateral port communicating with said annulus;

a first fluid flow path extending from the well and up through the tubing flowbore, said first aperture, and first lateral port;

a second fluid flow path extending from the well and up through said annulus, said second aperture, and second lateral port to the surface; and

circulating fluids from the annulus to the surface through the second fluid flow path.

18. An apparatus for controlling fluid flow in a subsea well having a subsea wellhead supporting a casing string at the subsea floor, comprising:

a first hanger suspended by the subsea wellhead at the subsea floor, said first hanger being unsealed with the wellhead;

said first hanger supporting a first pipe string within the well, said first pipe string forming a first annulus with the casing string;

a mandrel connected to the wellhead and having an aperture forming a mandrel wall having first, second, and third ports disposed in said wall;

a second hanger landed in said mandrel having first, second, and third apertures in fluid communication with said first, second, and third ports, respectively, said second hanger supporting a second pipe string within the well having a flow bore communicating with said first aperture and first port, said first and second pipe strings forming a second annulus;

said second aperture and second port communicating with said second annulus and said third aperture and third port communicating with said first annulus;

a first fluid flow path extending from the well and through the tubing flowbore, said first aperture and first port;

a second fluid flow path extending from the well and through said second annulus, said second aperture and second port; and

a third fluid flow path extending from the well and through said first annulus, said third aperture and third port.

19. The apparatus of claim **18** further including a sleeve sealing with said mandrel below said second aperture and sealing with said first hanger, said sleeve forming passageways between said first annulus and said third aperture and between said second annulus and said second aperture.

20. A spool tree assembly having a blowout preventer mounted thereon for operating a high pressure subsea well, the blowout preventer having a flow bore with at least lowermost rams adapted to close the flowbore, and choke and kill lines extending from the flowbore below the lowermost rams to the surface, the assembly comprising:

a spool body having a generally cylindrical internal wall forming a spool body central bore therethrough with a lateral production passage extending from said spool body central bore;

a tubing hanger assembly mounted in said spool body central bore and having a central passageway with a lateral production passageway extending from said tubing hanger central passageway and in alignment with said spool body central passage, the tubing hanger assembly further including tubing without a submersible pump, an annulus being formed around said tubing;

said internal wall of said spool body having a production port in fluid communication with said production passageway, a workover port in fluid communication with the choke and kill lines through the blowout preventer flowbore below the lowermost rams, and an annulus port in fluid communication with said annulus;

an internal closure member in the spool body central bore above the tubing hanger assembly;

said workover port extending exteriorly of said spool body central bore to a valve in fluid communication with a conduit extending to the surface; and

said annulus port extending exteriorly of said spool body central bore to a valve in fluid communication with a conduit extending to the surface.

21. An apparatus for use selectively with a blowout preventer for controlling the flow of fluids in a well, the blowout preventer having at least one choke and kill line extending to the surface, comprising:

a production member adapted for disposal below the blowout preventer, said production member having a central bore formed by a wall of said production member and a production passageway and an annulus passageway in said wall;

a production valve disposed with said production member for controlling flow through said production passageway;

an annulus valve disposed with said production member for selective fluid circulation downhole through said annulus passageway;

a tubing hanger supported and sealed within said production member and suspending tubing in the well, said tubing hanger and tubing having a flowbore and forming an annulus in the well, said tubing hanger having an aperture communicating said flowbore with said production passageway, and said annulus passageway communicating with said annulus;

a conduit extending to the surface and in fluid communication with the flowbore;

said annulus passageway in fluid communication with the choke and kill line;

said production passageway in fluid communication with said annulus passageway; and

fluid circulation paths being formed from the surface through said conduit and the choke and kill line between said tubing hanger flowbore and annulus passageway to selectively circulate downhole using said tubing flowbore and tubing annulus.

22. The apparatus of claim 21 wherein said production member further includes a workover passageway in said wall, said workover passageway extending laterally into said central bore;

a workover valve disposed with said production member for selective fluid circulation through said workover passageway;

said annulus passageway in fluid communication with said workover passageway;

said workover passageway in fluid communication with said production member central bore above said tubing hanger;

said production member central bore being adapted for fluid communication with the choke and kill line; and

a fluid circulation pathway being formed between said production member central bore, workover passageway, and annulus passageway to selectively circulate downhole using said tubing flowbore and tubing annulus.

23. A method for controlling fluid flow in a well comprising:

suspending tubing from a tubing hanger;

supporting and sealing the tubing hanger within the bore of a production member for selective disposal below a blowout preventer having a blowout preventer bore;

forming a common flow passageway between the blowout preventer bore and a portion of the production member bore above the seals around the tubing hanger;

extending a tubular member into the blowout preventer bore, attaching the tubular member to the tubing hanger, and closing the blowout preventer therearound;

forming a flowpath through the tubing and the tubular member, forming an annular area between the tubular member and the production member in the common flow passageway and forming an annulus around the tubing below the tubing hanger;

forming an annulus passageway from the annulus and through the wall of the production member;

controlling flow through the annulus passageway by an annulus valve;

forming a workover passageway from the annular area and through the wall of the production member;

controlling flow through the workover passageway;

providing fluid communication between the workover passageway and the annulus passageway; and

circulating fluid downhole using the flowpath, tubing annulus, annulus passageway, workover passageway, and annular area.

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